norden

Reducing Climate Impact from Fisheries

A Study of Fisheries Management and Fuel Tax Concessions in the Nordic Countries

norden

Reducing Climate Impact from Fisheries

A Study of Fisheries Management and Fuel Tax Concessions in the Nordic Countries

Staffan Waldo, Hans Ellefsen, Ola Flaaten, Jónas Hallgrimsson, Cecilia Hammarlund, Øystein Hermansen, John R. Isaksen, Frank Jensen, Marko Lindroos, Nguyen Ngoc Duy, Max Nielsen, Anton Paulrud, Fredrik Salenius and Daniel Schütt

TemaNord 2014:533

Reducing Climate Impact from Fisheries
A Study of Fisheries Management and Fuel Tax Concessions in the Nordic Countries
Staffan Waldo, Hans Ellefsen, Ola Flaaten, Jónas Hallgrimsson, Cecilia Hammarlund,
Øystein Hermansen, John R. Isaksen, Frank Jensen, Marko Lindroos, Nguyen Ngoc Duy,
Max Nielsen, Anton Paulrud, Fredrik Salenius and Daniel Schütt

ISBN 978-92-893-2783-1
ISBN 978-92-893-2784-8 (EPUB)
http://dx.doi.org/10.6027/TN2014-533

TemaNord 2014:533
ISSN 0908-6692

Layout: Hanne Lebech
Cover photo: Photodisc

Print: Rosendahls-Schultz Grafisk
Copies: 116

Printed in Denmark

www.norden.org/en/publications

Nordic Council of Ministers
Ved Stranden 18
DK-1061 Copenhagen K
Phone (+45) 3396 0200

www.norden.org

Content

Preface

Few doubt the impact from human activities on global warming and the negative consequences of rising temperatures for both terrestrial and marine ecosystems. Efficient policy instruments are needed to change the development. Fisheries are, as is marine shipping, exempted from fuel taxation which causes higher fuel consumption than optimal. Economic instruments such as CO_2 taxes and emission trading systems might be introduced to reduce fuel consumption, but fisheries managers also have other instruments at hand. Large fish stocks and efficient fleets might reduce fishing effort and still maintain catch levels. In the report *The Impact of Abolishing Fuel Tax Concessions in Fisheries* policy instruments for reducing CO_2 emissions are empirically analyzed for fisheries in the Nordic countries Sweden, Denmark, Norway, Iceland, Greenland, Faroe Islands and Finland. The aim of the report is to provide input to the work on reducing the climate impact from fisheries. The intended readers are civil servants, politicians, researchers, and stakeholders with an interest in fisheries and climate issues.

The report is part of the project *Ekonomiska konsekvenser av ett avskaffande av bränslesubventioner för fiskefartyg* (Economic impact of abolishing fuel tax concessions for fishing vessels) funded by the Nordic Council of Ministers. Additional funding is provided by the Swedish Research Council Formas, and the AgriFood Economics Centre. The project is coordinated by Staffan Waldo at AgriFood Economics Centre, SLU. Case studies for each country are provided by national research groups. Responsible for the Danish case study is Max Nielsen and Frank Jensen, both University of Copenhagen. The Greenlandic case is provided by Daniel Schütt at Statistics Greenland, Max Nielsen, and Frank Jensen. The Icelandic case is provided by Jónas Hallgrimsson at University of Iceland, the Faroese case by Hans Ellefsen at Faroese Ministry of Fisheries, and the Finnish case by Fredrik Salenius at University of Helsinki. The Norwegian case is provided by Ola Flaaten and Nguyen Ngoc Duy at University of Tromsø, and Øystein Hermansen and John R. Isaksen at Nofima. Sweden has two case studies, one provided by Staffan Waldo and Cecilia Hammarlund at AgriFood Economics Centre, and the other by Staffan Waldo and Anton Paulrud (Swedish Agency for Marine and Water Management).

The authors acknowledge input from participants at the seminar "Energy Efficiency in Fisheries" in Lysekil, Helena Johansson, Roger Martini, Ronggang Cong, Johan Blomquist, Cecilia Carlsson, and Dadi Már Kristófersson.

Ewa Rabinowicz
Head of unit, AgriFood Economics Centre
Swedish University of Agricultural Sciences (SLU)

Summary

Fuel use is a main contributor to the environmental impacts of fisheries, accounting for about 1.2% of global oil consumption and resulting in 130 million tons of CO_2 emissions. Since fisheries are exempted from fuel taxes and existing trading systems for CO_2 emission rights, the incentives to reduce fuel consumption are smaller than justifiable from a climate perspective. This results in higher fuel use than is optimal. But emission levels are also determined by fisheries policies such as stock sizes and fleet efficiency. This report uses models that integrate economics and biology to analyze how CO_2 emissions, fleet structure, economic performance and employment opportunities are affected by efficient fisheries policies and by imposing fuel taxes or CO_2 trading schemes in Nordic fisheries.

Four different scenarios for imposing the costs of CO_2 emissions on fisheries are analyzed. The first scenario in the project is a "baseline" scenario in which the fuel tax concessions are maintained,[1] but the stock and fleet sizes are managed in order to generate the maximum economic outcome. In the second scenario ("EU") the fishery is assumed to be part of the EU trading system for CO_2 emission rights, and the additional cost of fuel is thus the cost of buying emission rights in the market. In the third scenario ("Stern") a tax corresponding to the cost of CO_2 emissions, as calculated in the Stern report, is imposed on the fisheries, and in the fourth scenario ("National") fuel is taxed in the same way for fishers as for private citizens in the country.

To get a representative view of the Nordic fisheries, the analysis contains case studies from all the Nordic countries: Sweden, Denmark, Norway, Iceland, Greenland, the Faroe Islands and Finland. All data is from 2010. The 18 fleet segments analyzed range from coastal small-scale trap nets for salmon in Finland, with a total turnover of about EUR 0.2 million, to large off-shore Norwegian and Icelandic trawlers, with a turnover of more than EUR 325 million. The three models used

---

[1] Icelandic fisheries are exempt from energy taxes but not CO_2 taxes, see appendix C for further details. In 2013 a reduced CO_2 tax was introduced for the Norwegian fishing fleet.

here are all well established in the literature. They differ in how they model the fisheries, the time frame, the interaction between fishing and stock development, etc. and thus contribute different dimensions to the analysis. In all, the report models 7 countries, 18 fleet segments, 25 fish stocks, one full-scale national fishery (Sweden), and one extension where the processing industry is included in the analysis (Greenland).

Currently, several of the analyzed fisheries have negative economic outcomes, and paying for CO_2 emission rights or fuel taxes will further reduce their economic viability. Others are more robust to increased fuel costs and will still be able to generate income to society. Still, managing Nordic fisheries in an economically optimal way will increase both economic viability and fuel efficiency substantially compared to the present management systems. Optimal fisheries management implies that the fleet size is set to an efficient level, and that stocks are rebuilt to maximize the economic performance of the sector. *This would reduce fuel consumption from 473 to 336 thousand m^3 (29%)* decrease the analyzed fishing fleet from 1,345 vessels to 737 vessels (45%), and improve economic performance by over 100%.

Introducing fuel taxes or an emission trading system in an optimally managed fishery will have limited effects on CO_2 emissions, fleet size, economic performance, and employment opportunities. Imposing fuel taxation corresponding to national fuel tax levels on the optimally managed fishery would imply a reduction of the fleet by approximately 80 vessels in total, and a reduction in fuel consumption of 39 thousand m^3. Thus, the well managed fishery is robust to changes in fuel prices and the fishery will be able to pay its external costs for CO_2 emissions.

The increase in fuel efficiency in optimal management is due to healthy stock levels and fishing fleets without over capacity, and is obtained without investments in new gear technology or management measures restricting fuel-intense fishing methods. However, the analysis also shows that an optimal fishery in some cases might imply increased use of fishing techniques with higher fuel use per volume caught. This is the case for the Icelandic fishery, which is already run with high efficiency.

To summarize, the analysis shows that optimizing the fishery by stock recovery and reducing excess fleet capacity is an efficient instrument to both reduce the climate impact of the sector and improve the economic outcome. Introducing fuel taxes or an emission trading system in the optimized fishery will have small effects on CO_2 emissions, fleet size and employment opportunities.

1. Introduction

Fuel use is a main contributor to the environmental impacts of fisheries (Avadí and Fréon, 2013), accounting for about 1.2% of global oil consumption and resulting in 130 million tonnes of CO_2 emissions in the year 2000 (Tyedmers *et al*. 2005). The role of CO_2 emission in global warming is well documented, and several attempts have been made to reduce emissions on a global level. Two regulatory instruments for doing this are taxes and trading systems for emission rights. This increases the cost of fossil fuel for private companies, and thus creates incentives to lower the level of emissions. However, since fisheries are exempted from fuel taxes and existing trading systems in the Nordic countries,[2] the incentives to reduce fuel consumption are smaller than justifiable from a climate perspective. This results in higher fuel use than is optimal.

Fuel tax exemptions fall within both the OECD and WTO definitions of a fisheries subsidy (OECD, 2006), and the topic was raised in the WTO trade round of negotiations in Doha (WTO, 2005; Sumaila *et al*. 2007; Sumaila, 2013), as well as in the public debate (WWF, 2007). Global fisheries subsidies amount to between US$ 25 and 29 billion, of which 15–30% consists of fuel subsidies (Sumaila *et al*., 2010). This is the largest share of what the authors define as capacity-enhancing subsidies, i.e. subsidy programs that lead to overfishing.

Abolishing fuel tax concessions will generate incentives to reduce fuel consumption; e.g. van Marlen *et al*. (2009) show that technological adaptations in the European fisheries could generate energy savings between 5 and 20% in most cases (with some fisheries reaching 40%). An adaptation to lower fuel use has already started due to high world market prices for oil (Cheilari *et al*., 2013), and both public and private investments are being made to reduce fuel consumption (see e.g. Parente *et al*., 2008; Matsushita *et al*., 2012; Priour, 2009). Further, fuel use is strongly related to fishing gear and target species (Thrane, 2004, Ziegler and Hansson, 2003; Schau *et al*., 2009; OECD, 2013), where pas-

---

[2] Icelandic fisheries are exempt from energy taxes but not CO2 taxes, see appendix C for further details. In 2013 a reduced CO_2 tax was introduced for the Norwegian fishing fleet.

sive gear is more fuel efficient. Thus, the fundamental choice of using fishing technologies based on active (e.g. trawl) or passive (e.g. gill-net, hook or traps) gear is important for fuel use in the fishing sector.

However, technology is only part of what determines fuel use, and e.g. Ziegler and Hornborg (2013) point out that stock size is highly important for fuel use. Excess capacity and over fishing are well known issues in fisheries management, and many Nordic fisheries are far from optimally managed regarding both stock size and fleet efficiency. Since large stocks and efficient fishing fleets will increase the catches per fishing effort, a biologically and economically well managed fishery is expected to reduce fuel consumption in addition to having positive effects on fleet profitability and stock status. Thus, to obtain an optimal fishery, the management should consider both the traditional problem with stock and fleet sizes and the costs of CO_2 emissions from fuel consumption.

The aim of this report is to provide fisheries managers with information regarding how abolished fuel tax concessions will affect CO_2 emissions and the industry structure, and to relate these to effects of management measures improving stock status and fleet efficiency. This is done in two steps. The first is a calculation of how additional fuel costs would affect the economic outcome in the current fleets. This is based on account statistics (no bio-economic models are used). This approach reflects a “static” situation when the tax is imposed, and does not take into account the fact that fishing will adapt to the new conditions in the long run. In order to analyze long-run changes, bio-economic models are needed. The second step of the analysis estimates the optimal management with regard to stock size and fleet structure. This is compared to the current situation and to a situation with optimal management combined with regulatory instruments for CO_2 emissions. Thus, the analysis will show the climate benefits of optimal fleet and stock management, as well as further climate benefits and changes in fleet structure etc. due to CO_2 regulatory instruments. This will provide information about how the Nordic fisheries will adapt to the different management measures. Indicators used for describing the development are CO_2 emissions, fleet size, fleet structure, employment, economic performance (resource rent), and fuel efficiency (catch/liter and value/liter).

Ideally, a CO_2 tax should reflect the costs of emissions for society, but these costs are difficult to calculate, and in practical climate policies different systems are in place simultaneously. In this report, four different scenarios for imposing the cost of CO_2 emissions on the fishery are analyzed. The first scenario in the project is a “baseline” scenario in which the fuel tax concessions are maintained, but the stock and fleet sizes are managed in order to generate the maximum economic outcome. The analysis compares this to both the current fishery and to optimized fisheries with different fuel costs. In the second scenario ("EU") the fishery is assumed to be part of the EU trading system for CO_2 emission rights, and the additional cost for fuel is thus the cost of buying emission rights in the market. In the third scenario ("Stern") a tax corresponding to the cost of CO_2 emissions, as calculated in the Stern report, is imposed on the fisheries, and in the fourth scenario ("National") fuel is expected to be taxed for fishers in the same way as for private citizens in the country. This typically involves both a CO_2 tax and an energy tax.

To get a representative view of the Nordic fisheries, the analysis contains case studies from all the Nordic countries; Sweden, Denmark, Norway, Iceland, Greenland, the Faroe Islands and Finland. The 18 fleet segments analyzed range from coastal small-scale trap nets for salmon in Finland, with a total turnover of about EUR 0.2 million, to large offshore Icelandic trawlers, with a turnover of more than EUR 325 million. The data is from 2010. The three models used here are all well established in the literature. They differ in how they model the fisheries, the time frame, the interaction between fishing and stock development, etc. and thus contribute different dimensions to the analysis. In all, the report models 7 countries, 18 fleet segments, 25 fish stocks, one full-scale national fishery (Sweden), and one extension where the processing industry is included in the analysis (Greenland).

2. Market Failures and CO_2 Emissions in Fisheries

According to economic theory free markets allocate resources efficiently. However, this is not the case in the presence of market failures. External effects (externalities) are examples of market failures which occur when an activity imposes a cost on others, and the cost is not borne by the one causing it. This report analyzes two externalities in fisheries. The first is the well know common pool problem where open access to a fish stock will lead to excess fleet capacity and over fishing (Clark, 1990). This externality occurs in a situation where fishermen have unlimited access to a limited resource. The second externality is the fuel tax exemption where fisheries do not pay the full cost of CO_2 emissions, which results in too large emission levels. Both externalities need to be addressed when formulating public policies.

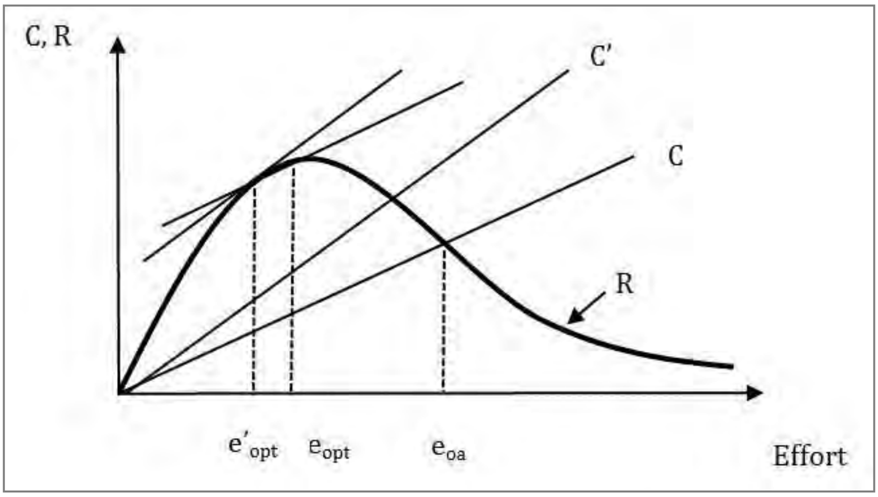
An extensive literature exists on governmental policies addressing the common pool problem in fisheries (see e.g. OECD, 2013b). Although many solutions exist, the most commonly used in Nordic countries are vessel licensing and quota systems with varying degrees of individual tradable quotas (ITQ). We do not go further into the discussion on ITQs and other management systems, but note that there exist ways of introducing a management scheme that ensures efficient resource allocation. This is presented here as an optimally managed fishery.

As mentioned above, not paying the full cost for CO_2 emissions is defined as an externality. Since CO_2 emissions are costly to society due to global warming, and since fisheries do not pay CO_2 taxes, the emissions in this study fall within the definition. The size of the externality is difficult to estimate, and three different levels are discussed in the chapter on Fuel Cost Scenarios.

Since fisheries do not pay for CO_2 emissions, they do not need to include these costs in the calculations when deciding when, where and how to fish. In order to reduce emissions, fisheries need to face the true social costs, i.e. the emission cost for society should be included in the price of fuel. There are two ways of doing this. The first is taxation and the second is emission trading systems. By taxing fuel at a level that reflects society's costs for emissions, these costs will be paid by the industry. National fuel taxation is common and used to varying extents by all countries in this study except the Faroe Islands. However, in all the countries but Iceland, fisheries are exempt from CO_2 taxation. In an emission rights trading system a cap on total emissions is defined, and companies need to buy emission rights on the market. This kind of system is implemented in the EU, but fisheries are currently not included. Both taxation and emission trading require that the regulatory instrument (the tax rate and emission quota) is optimally set. This is not necessarily the case with the present management in Nordic countries, since CO_2 costs to society are difficult to estimate, and fuel taxes are used for fiscal reasons as well as environmental.

The effects of public policies that correct the externalities discussed can be illustrated graphically. In figure 1 the open access situation as well as optimal management with emission is shown.

Figure 1. Open access and optimal management



The figure shows a standard bio-economic model with effort on the x-axis and costs and revenues on the y-axis. C is the cost of fishing and R is the revenue. For any given level of effort, the resource rent is the difference between revenue and cost. The open access equilibrium, which is where there is no resource rent in the fishery (R=C), occurs at effort level e_{oa}.[3] In optimal fisheries management the resource rent is maximized. This corresponds to effort level e_{opt} where the difference between the R and C curves is largest. Compared to open access, effort and costs have decreased and resource rent increased. As mentioned above an externality arises with fuel consumption. This is a social cost which shifts the cost curve to C´. The new optimal management would be at e'_{opt}, i.e. effort is further reduced.

As the figure is drawn, the change in effort and catches (revenues) is considerably larger from optimizing the fishery than when fuel consumption externalities are included. This will, however, depend on the size of the externality and on how close the fishery is to open access and optimal management. In a well-managed fishery the changes in going from current to optimal management will be small compared to a fishery that is managed closer to the open access situation. In the chapter on Estimated Impact we compare the current situation (without externalities), with the optimal management without externalities (baseline) to evaluate how close current management is to optimal. The baseline is compared to three scenarios with CO_2 management options for taking externalities into account.

A topic that is not illustrated above is technological adaption. Higher fuel costs will affect fuel-intense fishing gear more than other gear. Typically, trawling is more fuel intense than passive gear such as gill-nets and hooks. Thus, we could expect fishermen to adjust to the new situation by using more passive gear. On the other hand, in many cases trawling is more economically viable than passive gear, and might therefore be more robust to higher costs. The total effect on the fleet will be an empirical question.

It is important to note that imposing fuel taxation or a trading system on Nordic fisheries alone will make the sector less competitive on the international market. If this causes fish production to move to countries with lower fuel costs, or if fuel bunkering in international waters were to take place, the effect on global warming might be small. However, moving production might be more difficult in fisheries than in many other industries, since the resource cannot be relocated. We do not elaborate further on this topic in the analysis.

---

[3] In actual open-access fisheries, cost efficiency often varies between vessels, resulting in "producer's surplus" or "intra-marginal rent" for some vessels, implying a progressively increasing C-curve in Figure 1. For a theoretical discussion see Copes, 1972, and Duy *et al*., 2012 for a recent empirical investigation.

3. The Models

This section provides a short description of the three models used in the analysis. The first model, developed by Nielsen *et al*. (2012), is used by all the countries except Finland. In the Finnish case, a special model for salmon fisheries is used. To complement the analysis, the Swedish fishery is analyzed by an additional model (the Swedish Resource Rent Model for the Commercial Fishery, SRRMCF) that covers the entire Swedish fishing fleet. By using three alternative models we ensure that the results are robust to the different modeling approaches. For the interested reader, the models are described in the annexes and in the scientific literature.

3.1 Model Descriptions

The same model is used for Sweden, Denmark, Norway, Iceland, Greenland and the Faroe Islands. The model optimizes the long-run economic performance (given exogenous input and output prices) for included vessel segments by changing the fishing effort until fishing takes place where the stock is at the Maximum Economic Yield (MEY), and the fishing fleet is efficiently utilized. Thus, the model includes both biologic and economic components. The biological part of the model allows changes in the stock size in order to maximize the economic outcome of the fleets. This part is less developed than the Finnish salmon model, but more than the Swedish SRRMCF model. On the other hand, the model contains more fleet segments than the Finnish model, but is less detailed than the SRRMCF model. For example, all the segments are assumed to be inflexible regarding which stocks they utilize, and will thus always fish the same share of each species as observed in the data. The model is implemented in Excel and both multiple stocks and multiple fleet segments are allowed. For further information, see Nielsen *et al*. (2012) and appendix B.

The Finnish salmon model (Kulmala *et al*. 2008) is presented in the Finnish case study in appendix C. This is an age-structured model that takes the entire life cycle of the Torne River salmon into account: from smolt in the river, following the migratory pattern throughout the Baltic basin, and back to the spawning grounds and the birth of new generations. The objective of the model is to maximize the Net Present Value of the salmon fishery over a 50-year period. The Finnish salmon model has the most developed biological part of the three models, but, on the other hand, only includes one fishing segment and one species.

The analysis of the Swedish fleet is complemented with an additional model, the SRRMCF model. The model covers all Swedish fleet segments and commercially utilized stocks. Focus in the model is on an economically efficient utilization of available catch quotas. The model includes about 200 fishing operations (métiers) which are defined from gear used, target species, fishing areas, etc. (Waldo and Paulrud, 2013). The objective of the model is to maximize the total economic performance of the fleet. The biological dimension in the model is reduced to agreed quotas, a simplification which makes it possible to perform an in-depth economic modeling of the fleet behavior. The fleet segments are assumed to be fully flexible to choose among métiers that are possible for the type of vessels included in the segment (e.g. trawler, gill-netters), and therefore able to adjust their catch composition in accordance with what is optimal for the new conditions imposed by abolishing fuel tax concessions.

3.2 Profit and Resource Rent

All the models in the analysis are used for estimating both profit and resource rent. Profit is the profitability observed by the fishery, while resource rent is the economic rent from the fish resource. In the appendices both profit and resource rent estimations are presented, but in the report below all figures are from resource rent estimations. In previous reports for the Nordic Council (Nielsen et al. 2006) the resource rent is defined as "the net surplus that, at a given time, remains for the remuneration of capital and labor above the rate that is achieved in other businesses."

The remuneration to labor and capital are calculated differently for profit and resource rent. As an illustrative example of the concepts, assume an employed fisherman earns a wage of EUR 1,000 from a fishing operation, while the remuneration in alternative employment for the same time spent working, all other things equal, is EUR 700. In the calculation of profitability the observed wage EUR 1,000 is included as a cost, but EUR 300 of this is actually "surplus" from the fishery that is allocated to the fisherman. He/she would not be able to get this wage anywhere else. In the calculation of resource rent this is taken into account and

EUR 700 is used as the wage. The difference of EUR 300 is defined as being surplus from the fishery that benefits society (in this case the benefit to society is allocated to the employed worker, being part of the intra-marginal rent). The calculation of resource rent applied in this report includes intra-marginal rent and therefore over-estimates the rent to the resource.

3.3 Fuel Taxes in Current Fisheries

The models analyse the outcome in a fishery with optimal management. However, many Nordic fisheries are far from optimally managed. To get a picture of the economic viability of current fisheries in a situation with fuel taxes, the performances of the fleets are calculated based on account data. This is done by subtracting the additional fuel costs from the current economic result, assuming that all other things are equal. This is a short term analysis where the fishermen do not change their fishing behavior. Thus, the aim of this calculation is not to estimate changes in fleet structure etc. Such changes need to be estimated with the bio-economic models.

3.4 Interpretation of Model Results

Bioeconomic models like the ones presented above are simplified versions of actual fisheries that attempt to include relevant relations between economic and biological factors. Of course, it is not possible to include all aspects of a fishery that influence the economic and biological performance. Thus, the results should be interpreted with caution, and we do not focus on Euros or kilos of catch in the analysis, but rather the direction in which the fishery will move; to some extent we compare the magnitude of the change between scenarios. Each country is provided with a *baseline scenario* which is interpreted as the optimal fishery according to the model with the present fuel costs. In the baseline scenario the stocks and fleets are allowed to adjust in a way that maximizes the economic outcome of the fishery. We compare the current fishery to the baseline in order to evaluate the effects of implementing an optimal fisheries management as compared to the current one. Further, the effects of changes in fuel costs are compared to the baseline situation in order to evaluate the effects of taxes and emission rights in optimal management.

4. Data

Fishing segments suitable for the analysis have been identified for each country. The segments are important fisheries for the national fleet, and are chosen to represent both active and passive gear. Active and passive gears are expected to have different fuel efficiency and different importance for local employment opportunities etc. A short description of the fleet segments used in the analysis is presented below, followed by utilized fish stocks, and physical and economic data.

4.1 Fleet Segments

For *Sweden*, two models with different fleet segments are used; the Nielsen model and the SRRMCF. In the Nielsen model four fishing segments are analyzed: Vessels 10–12 m using passive gear and vessels 12–18 m, 18–24m and 24–40 m using active gear. The vessels using passive gear primarily fish with gill-net and hook while the vessels using active gear primarily use trawl. The analysis is restricted to Baltic Sea fisheries and the main target species is cod, but herring and sprat are also included in the analysis. The SRRMCF model contains the entire Swedish fleet represented by 24 fleet segments fishing all stocks available for Swedish fishermen.

For *Denmark,* three fleet segments are analyzed: Net/hook <12 m, gill-net and hook 12–18 m, and trawl <18 m. The target species are cod, sole, plaice, Nephrops, sand eel and sprat in both the North Sea and the Baltic Sea.

For *Norway,* two fleet segments are analyzed: Coastal vessels 11–15 m and ocean trawlers >30 m. The target species are cod, saithe, haddock and monkfish. The coastal vessels primarily use gill-net and longline on the Norwegian coast, while the trawlers fish in both the Norwegian and Barents Seas.

For *Iceland,* four vessel segments are analyzed: Small vessels with 10–200 GT (gross tonnage) primarily using passive gear, medium sized vessels with GT >200 primarily using trawl, trawlers, and freezer trawlers with on-board processing. The main species are cod, haddock and saithe.

For *Greenland,* two fleet segments are analyzed: In-shore trawlers and off-shore trawlers. Both segments utilize the Northern shrimp stock (NAFO subareas 0 and 1). The two trawling segments have different management regulations, where the off-shore trawlers process 75% of the harvest on board, leaving 25% for on-shore processing in Greenland, while in-shore trawlers are obligated to land 100% for on-shore processing.

For the *Faroe Islands,* two fleet segments are analyzed: Trawlers and long-liners, both targeting cod, haddock and saithe at the Faroe Plateau.

The *Finnish* analysis is based on one fleet segment fishing for Torne River salmon and using trap-nets along the Finnish Baltic Sea coastline in the Gulf of Bothnia.

4.2 Fish Stocks

The analyzed fisheries contain 25 stocks in the North Sea, Baltic, Skagerrak, Kattegat, North-east Arctic, Faroe Plateau, West of Greenland, and Icelandic waters. The stocks targeted are presented in table 1 together with information on the sustainability of current fishing mortality.

Table 1. Fish stocks

Country	Species	Sea	Area	Fishing mortality 2010*
Sweden	Cod	Baltic	25–32	Appropriate
	Herring	Baltic	22–24, IIIa	Appropriate
	Herring	Baltic	30	Appropriate
	Sprat	Baltic	IIId	Below target
	Cod	Baltic	22–24	Above target
	Herring	Baltic	25–29	Above target
Denmark	Nephrops	Skagerrak, Kattegat	3A	Appropriate
	Cod	Baltic	3D	Appropriate
	Plaice	North Sea	4	Appropriate
	Sole	S,K,WB	3 ABC	Below target
	Sole	North Sea	4	Above target
	Cod	North Sea	3AN+4	Above target
	Cod	Baltic	3BC	Above target
	Sand eel	North Sea, Skagerrack	3A+4	Not defined
	Sprat	Baltic	3BC	At risk
Norway	Cod	North East Arctic	1, 2	Appropriate
	Saithe	North Sea	4, 3A, 6	Appropriate
	Haddock	North East Arctic	1, 2	Appropriate
	Saithe	North East Arctic	1, 2	Not defined

Country	Species	Sea	Area	Fishing mortality 2010*
Iceland	Cod	Iceland, East Greenland	Va	Appropriate
	Haddock	Iceland, East Greenland	Va	Not defined
	Saith	Iceland, East Greenland	Va	Not defined
Greenland	Shrimp	West of Greenland	NAFO 0/1	Above target
Faroe Islands	Cod	Faroe Plateau	Vb1	Above target
	Haddock	Faroe Plateau	Vb1	Above target
	Saithe	Faroe Plateau	Vb1	Above target
Finland	Salmon	Baltic	22–31	Appropriate

*See appendix C for discussions and sources.

Of 25 stocks (observe that the two Baltic cod stocks are targeted by both Swedish and Danish vessels) 8 are considered to have fishing mortality above target, 12 appropriate or below target and 5 undefined. Although only a minority of the stocks is being over fished, the current fishing mortality should be reduced in eight cases for the fisheries to be long-run sustainable.

4.3 Physical and Economic Data

Table 2 contains the number of vessels, full time employment (FTE), days at sea per vessel (DAS) and turnover.

Table 2. Physical and Economic Data, 2010

Country	Segment	Vessels	FTE	DAS per vessel	Turnover (EUR million)
Sweden	Passive 10–12 m	55	36	96	2.3
	Trawl 12–18 m	15	23	91	3
	Trawl 18–24 m	29	79	109	11.1
	Trawl 24–40 m	13	28	97	6,5
Denmark	Net/hook < 12 m	130	103	99	23
	Net/hook 12–18 m	42	61	143	24
	Trawl <18 m	147	105	141	96
Norway	Coastal 11–15	342	855	196	80.4
	Ocean trawl	44	1,791	299	348.3
Iceland	Small 10–200 bt	255	950	250	131.1
	Medium >200 bt	68	750	250	149.9
	Trawl	25	400	250	107.9
	Freezer trawl	35	550	250	325.5
Greenland	In-shore trawl	31	251	168	41.2
	Off-shore trawl	9	321	294	110

Country	Segment	Vessels	FTE	DAS per vessel	Turnover (EUR million)
Faroe Islands	Trawl	30	211	241	59.9
	Long-line	16	221	246	23.6
Finland	Trap-net	59	59	55	>0.2
Total		1,345	6,794	-	1,544.5
Sweden SRRMCF	Demersal trawl	205	402		397
	Passive gear	422	281		152
	Pelagic trawl	63	216		397
	Total	690	900		947

In total 1,345 vessels with 6,794 full time employees and a turnover of over 1.5 billion Euro are modeled in the case studies, and 690 vessels with 900 employees in the Swedish SRRMCF model. Notably, the Norwegian and Icelandic fisheries are considerably larger than the others, and together constitute about 60% of the vessels and 70% of the employees in the analysis. Thus, Norway and Iceland will have a large impact on results that are presented as an aggregate of all the countries in the analysis.

5. Fuel Cost Scenarios

The analysis is based on the four scenarios in table 3. The first scenario is a benchmark with no fuel taxes. This corresponds to the present fuel tax situation where fisheries do not pay taxes or for emission rights. Iceland is an exception; the fishery pays a CO_2 tax of EUR 35.5 per m^3 in the present fuel tax scheme. In the second scenario the fishermen are assumed to buy emission rights in the European Emission Trading System (ETS; see European Parliament, 2011). In 2009 the price in the ETS was approximately EUR13 per tonne of CO_2, which corresponds to about EUR 34 per m^3 diesel. The third scenario is based on Stern's (2006) estimated costs for CO_2 emissions, which correspond to EUR 159 per m^3 diesel. The fourth scenario is defined as fisheries paying the same taxes as other users of fuel in the country, i.e. all tax exemptions are withdrawn. This scenario differs between countries and the national tax levels range from 0 to EUR 627 as presented in table 3. Both energy and CO_2 taxation are included in the national taxation.

Table 3. Definition of Fuel Scenarios

Scenario	Country	Euro / m3 diesel added to fuel price	Definition of national taxes
1. Benchmark		0	
2. EEX EU emission allowances 2009		EUR 34.	
3. Stern		EUR 159	
4. National taxation	Sweden	EUR 421	Energy tax, CO2 tax
	Denmark	EUR 366	Energy tax, CO2 tax
	Norway	EUR 311	Basic-, CO2 -, and NOx-tax
	Iceland	EUR 362	CO2 tax, Energy tax
	Greenland	EUR 13	Energy tax
	Faroe Islands	0	No taxation
	Finland	EUR 627*	Energy tax, CO2 tax, stockpile fee

*The Finnish tax is high since it is based on petrol engines, not diesel.

Of course, there are numerous alternative possibilities for defining the scenarios. The literature on costs of CO_2 emissions has suggested other levels than Stern (Nordhaus, 2007), and the price of EU emission allowances has varied considerably over the years. However, including additional scenarios would only marginally benefit the analysis, since they will be within the range of values already defined in the scenarios. Additional scenarios with low CO_2 costs would not differ substantially from the baseline, and the national scenario with both CO_2 and energy taxation covers high cost alternatives. The OECD (2012) provides an international comparison of fuel tax concessions.

6. Estimated Impact

Introducing fuel taxes/emission costs to the fishery will have effects on CO_2 emissions and on the economic and social sustainability of the fishing sector. Indicators of this, for the optimized fisheries, are found in the section for model results. However, the result section starts with the economic performance of current fisheries in the presence of fuel taxation.

All the figures in the results section are for the resource rent calculations, unless profit is explicitly stated. The resource rent represents the fisheries' economic contribution to society. The calculations for profitability can be found in the case studies in appendix C.

6.1 Short Term Impact

The first step in the analysis is the sensitivity of the resource rent in current fisheries to different estimates of society's cost for CO_2 emissions. These are represented by the fuel scenarios. The calculations are based on account statistics (i.e. no bio-economic maximization) where the additional CO_2 cost is subtracted from the current resource rent. In table 4 "+" represents a positive resource rent and "-" a negative one.

Table 4. Resource rent in current fisheries in different emission cost scenarios, "+" implies a positive resource rent and "-" a negative one

Country	Segment	No CO2 cost	EU	Stern	National
Sweden	Passive 10–12 m	-	-	-	-
	Trawl 12–18 m	+	+	+	-
	Trawl 18–24 m	-	-	-	-
	Trawl 24–40 m	-	-	-	-
Denmark	Net/hook < 12 m	-	-	-	-
	Net/hook 12–18 m	+	+	+	+
	Trawl <18 m	+	+	+	+
Norway	Coastal 11–15	+	+	+	-
	Ocean trawl	+	+	+	+
Iceland	Small 10–200 bt	+	+	+	+
	Medium >200 bt	+	+	+	+
	Trawl	+	+	+	+
	Freezer trawl	+	+	+	+
Greenland	In-shore trawl	+	+	+	+
	Off-shore trawl	+	+	+	+
Faroe Islands	Trawl	+	+	+	+
	Long-line	+	+	+	+
Finland	Trap-net	-	-	-	-

Of course, fisheries with negative resource rents, such as the Finnish and most of the Swedish, will also have negative rents in the fuel scenarios. A more interesting pattern that emerges in table 4 is, however, that fisheries with a positive resource rent in the current situation also tend to have positive rents in the fuel scenarios. In these cases society's benefits from the sector are larger than the costs, even in high cost scenarios. For the National scenario, the resource rent is approximately 30% lower than without CO_2 costs.

Iceland, Norway, Greenland and the Faroe Islands, where fishing is a relatively large share of the national economy, also tend to have fisheries with positive rents when imposing the highest CO_2 costs. Important is that the resource rent is calculated with the wage rate in alternative employment, and that in these countries the observed wages are higher in fisheries (i.e. part of the resource rent is allocated to wages rather than the vessel owners). If calculating the profitability, i.e. using observed wages, a larger share of the fisheries will face negative numbers.

6.2 Long Term Impact

The long term impacts are based on the model results. For Sweden, two models have been used. Unless the SRRMCF model is explicitly stated, the results are for the model developed by Nielsen *et al*. (2012). The SRRMCF model is not included in the calculation of "total" in the tables. Since some Swedish segments are included in both the SRRMCF and the model by Nielsen *et al*., these would be counted twice.

6.2.1 Fleet and Employment Effects

In the long run, fleet size, fleet structure and employment opportunities will change due to management changes. The effect on the fleet size is shown in table 5.

Table 5. Number of vessels, current (2010) and scenarios

Country	Current	Baseline	EU CO2	Stern	National
Sweden	112	39	39	36	34
Denmark	319	131	131	128	122
Norway	386	184	182	177	171
Iceland	383	327	328	320	294
Greenland	40	9	9	9	9
Faroe Islands	46	18	18	18	18
Finland	59	29	28	24	7
Total	1,345	737	735	712	655
Sweden – SRRMCF	*690*	*210*	*216*	*208*	*190*

The overall pattern in table 5 clearly shows that an optimized fishery (baseline), with an efficient number of vessels operating at MEY, implies that the total fleet size is substantially reduced compared to the current fishery in all cases. Imposing CO_2 costs on the condition that the fishery is optimized only has a limited effect on the number of vessels. The total number of vessels operating in the analyzed fleet segments is reduced from 1,345 to 737 when optimizing the model, but the reduction from a situation with full tax exemptions to the case with national taxation is only 82 vessels. The interpretation of the result holds for all of the three models that are used. The increase in number of vessels in the Icelandic EU scenario compared to the baseline is due to the fact that the Icelandic CO_2 tax in the baseline is higher than the EU price for emission rights. The increase in vessels in the Swedish SRRMCF model is due to a reallocation to smaller vessels.

The significant reduction of the fleet in the optimization, and the small changes due to fuel scenarios will also affect the employment opportunities in the fisheries sector. The full time employment is presented in table 6.

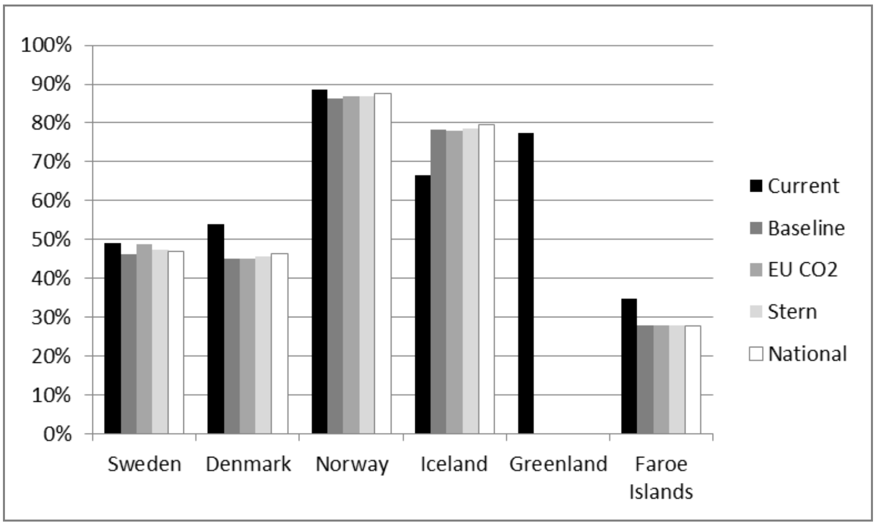
Table 6. Full time employment

Country	Current	Baseline	EU CO2	Stern	National
Sweden	167	79	77	71	67
Denmark	269	129	129	127	125
Norway	2,646	1,398	1,379	1,311	1,235
Iceland	2,650	2,075	2,083	2,015	1,813
Greenland	572	332	329	321	331
Faroe Islands	432	119	119	118	119
Finland	59	29	28	24	7
Total	6,795	4,161	4,144	3,987	3,697
Sweden – SRRMCF	*900*	*603*	*607*	*471*	*431*

The full time employment is reduced by about the same magnitude as the reduction in the fleet size. In total the fleet is reduced by 45% and employment by 38%. The difference is explained by a restructuring of the fleets where smaller vessels leave the fishery to a larger extent, while larger vessels with high employment stay. As an example, the Greenlandic fleet is estimated to be reduced by almost 80%, but employment only by about 40%. This is due to the large factory trawlers being more efficient, and the fact that, in an economically optimal fishery, the smaller in-shore trawlers with fewer employees will leave the fishery.

Figure 2 shows the share of vessels using passive gear and/or fishing in-shore for each country and fuel scenario.

Figure 2. Share of vessels using passive gear and/or fishing in-shore



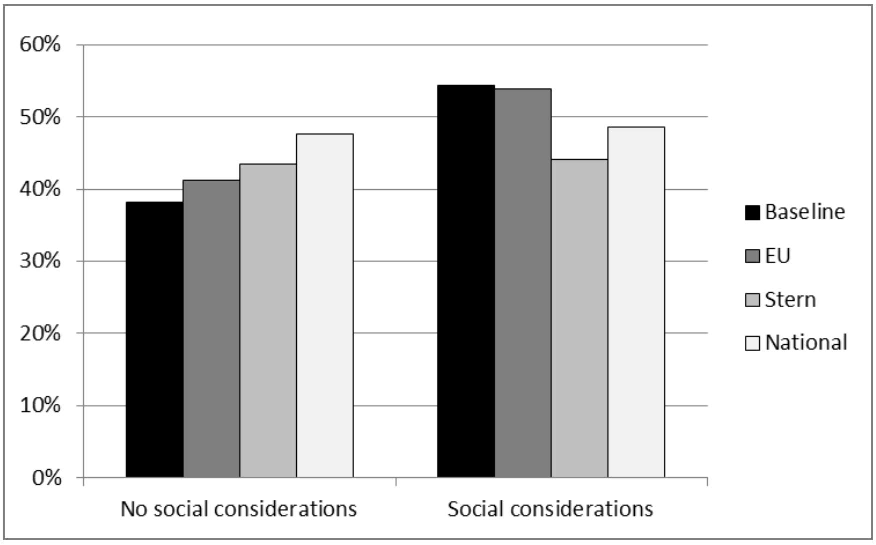
The share of passive/in-shore vessels is reduced in the model optimizations as compared to the current situation for all countries except Iceland. In Iceland the share of small vessels is increasing as a result of the combination of small efficient vessels staying in the fishery and trawling being concentrated to large freezer vessels.

Vessels using passive gear tend to be more fuel efficient (Avadí and Fréon, 2013), and higher fuel costs are thus expected to increase the use of passive gear compared to active. We find such effects in the data, but the increase is marginal and does not apply to all countries and scenarios. However, although the share of trawlers might be stable or even increase when fuel costs increase, this could be due to a more frequent use of smaller (and more fuel efficient) trawlers as is the case for e.g. Sweden.

Combining Fuel Taxes and Social Considerations

Many countries have policies to facilitate the development of the small-scale fleet and/or to protect it from being bought out from the fishery by larger vessels in a system with tradable fishing concessions. The aim of this is to keep local employment opportunities, keep harbors open, attract tourists, etc. Using the SRRMCF model, we illustrate the combination of such policies with fuel taxation policies for the Swedish national fleet. The Swedish quotas for cod and Norwegian lobster are split between passive and active gear in order to improve the situation for the small scale passive fleet. This is operationalized in the model as restrictions in possible reallocations of catches among segments. Figure 3 shows the results with and without social considerations.

Figure 3. Share of vessels using passive gear, Sweden



In the baseline without social considerations 38% of the Swedish vessels use passive gear. Higher CO_2 costs imply a larger share and in the National scenario almost 50% of the vessels use passive gears. In the case with social considerations a first observation is that, as expected, the share of vessels using passive gear is larger in the baseline scenario compared to without social considerations. When fuel costs increase, the vessels using passive gear are restricted from increasing their catches since reallocation of quotas is restricted, and thus the share does not increase. In the Stern scenario, it is no longer profitable for them to catch the allocated quotas, and the share of vessels using passive gear is reduced to the same level as in the management system without social considerations.

Thus, the effect of combining fuel taxes and social considerations is that allocating quotas is an efficient policy for small-scale fleet development, as long as the fuel costs are low enough to make utilization of the additional quotas profitable. This seems to be the case until a level somewhere between the EU and the Stern scenarios. Of course, in practical fisheries the fleet adaption will not be a sudden reduction, but a process where the least efficient fishermen will leave the fishery due to high fuel costs.

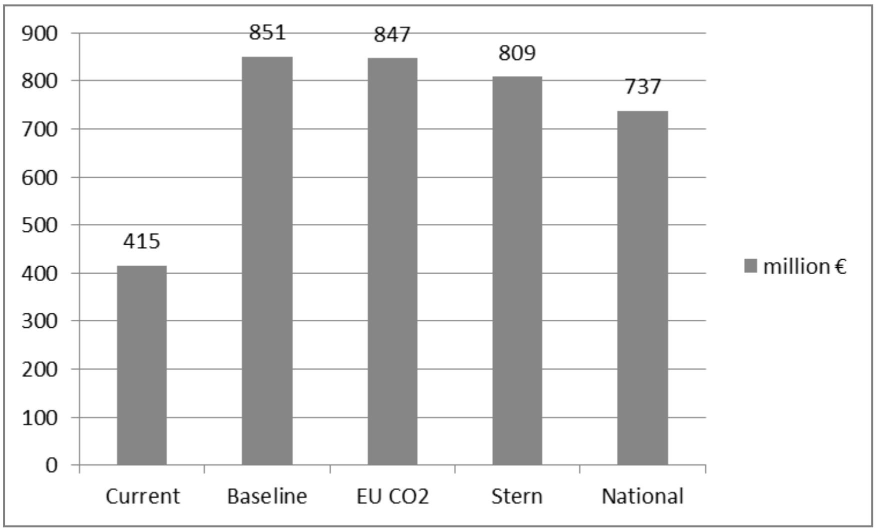
6.2.2 Economic Effects

The aggregate resource rent in the analyzed fisheries is EUR 415 million in the current situation, but could almost double in a situation with optimal management.[4] Taking CO_2 costs into account will by definition affect the economic outcome negatively. In the National scenario, resource rent decreases by about 13% compared to the baseline.

---

[4] A sensitivity analysis shows that even if the stock growth is overestimated, the baseline is substantially higher than the current situation. The sensitivity analysis is performed for profit maximization by reducing the a parameter in the model by 25%.

Figure 4. Aggregate Resource Rent for all Nordic Countries



Of course, both the possible gains from an optimal fishery and the changes in resource rent due to fuel taxes will differ among the countries, depending on how efficient the current fisheries management is and how sensitive the fleets are to fuel costs. The resource rent per country is presented in table 7.

Table 7. Resource Rent, million EUR

Country	Current	Baseline	EU CO2	Stern	National*
Sweden	-4.98	7.94	7.78	7.02	6.74
Denmark	75	234	234	229	222
Norway	55.4	106.3	104.5	97.8	91.2
Iceland	249	315	317	305	269
Greenland	34.0	89.7	88.7	85.4	89.3
Faroe Islands	12.0	56.1	55.9	55.4	56.1
Finland	-0.005	0.042	0.039	0.029	0.003
Sweden – SRRMCF	*3.10*	*33.2*	*32.0*	*28.4*	*26.0*

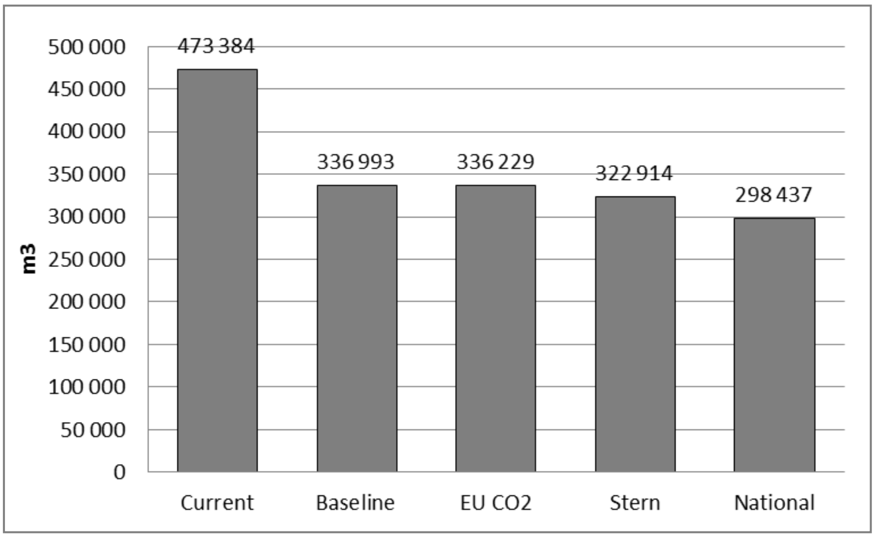
*The National scenario does not include governmental fuel tax revenues since these are assumed to cover society's cost for CO2 emissions. If at least part of the taxation is not due to CO2, this underestimates the true resource rent somewhat.

In the current fishery, all nations have positive resource rents except the Finnish salmon fishery and the Swedish Baltic Sea demersal fishery. The Swedish fishery in total, as shown in the SRRMCF model, generates a positive resource rent which is due to the economically successful pelagic fleet. The resource rent increases substantially for all countries when optimizing fishing as compared to the current situation. The countries with current fisheries that are most efficient compared to the optimized fisheries are Iceland and Norway. Higher CO_2 costs imply that the industry generates lower resource rent than in the baseline scenario, but all fisheries generate higher resource rents in the optimized fishery with fuel taxes than under current management.

6.2.3 Fuel Consumption

Fuel consumption will change if fuel taxes are imposed on the fishery. This in turn will affect both the total fuel consumption and fuel efficiency. The total fuel consumption for all countries for each scenario is presented in figure 5.

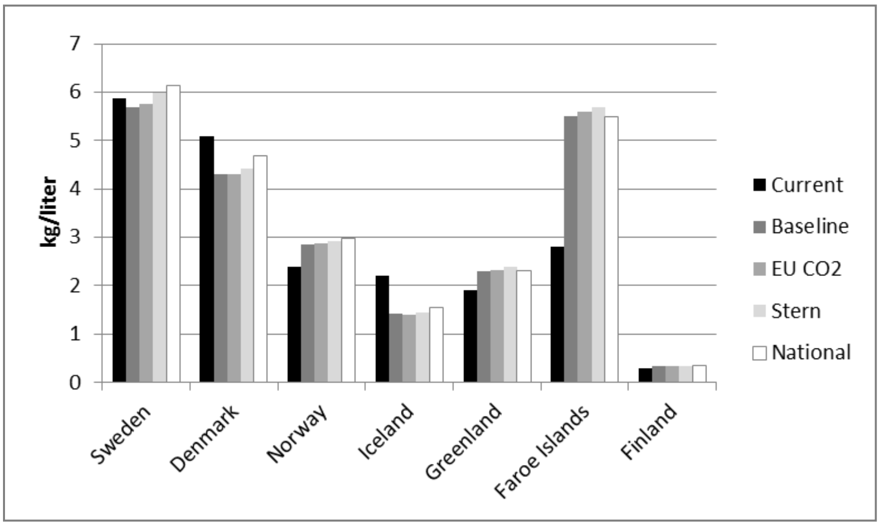
Figure 5. Aggregate fuel consumption in m^3 for all fisheries analyzed



The fuel consumption is significantly lower in an optimized fishery compared to the current management systems. The fuel consumption is also lower in scenarios with higher fuel costs (the national scenario has the highest fuel cost of most countries, but not all). However, the magnitude of the reduction due to higher fuel costs is low compared to optimizing the fishery.

Fuel efficiency can be measured in several ways (Patterson, 1996) and relates energy use to some kind of physical or economic output. Commonly used is the catch per liter of fuel, which is presented in figure 6. Observe that only catches of the main species (species included in the model) are included. These typically represent 60–80% of the total catch value in the current fishery.

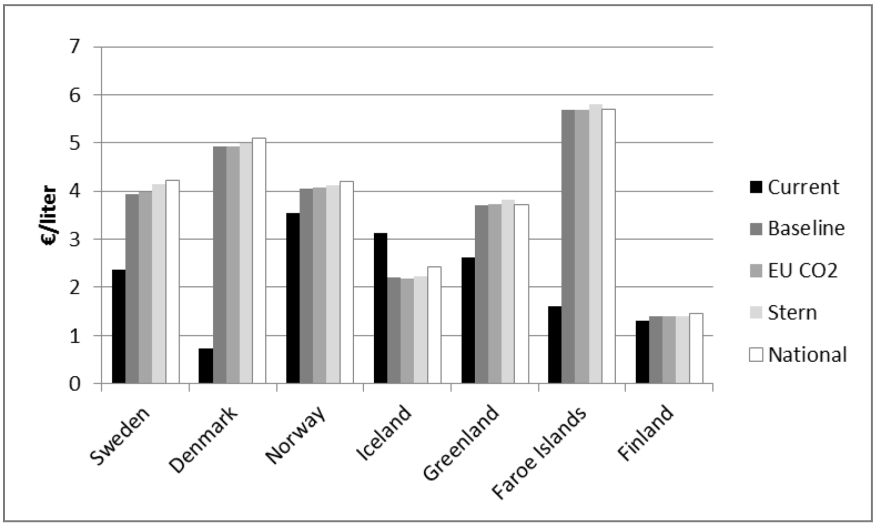
Figure 6. Catch of main species (kg) per liter fuel



When the current management system is changed to an optimal system in the baseline scenario, the catch per liter of fuel increases for Norway, Greenland, Faroe Islands and Finland, and decreases for Sweden, Denmark and Iceland. The large increase in fuel efficiency in the Faroe Islands is due to a significant stock recovery compared to the current situation. Lower fuel efficiency depends on reallocations of species (e.g. Swedish vessels reduce sprat catches, which are high volume but low value) or, as in the case of Iceland, reallocation of catches to larger and more fuel intense trawlers. Increasing the cost of fuel improves fuel efficiency for all countries.

An economic output measure does not only take into account the amount of fish caught but, through the price mechanism, also how much society values the landings. Observe that only the value of the main species (species included in the model) is included. Also observe that the National scenario implies high fuel costs for most countries, while Greenland and Faroe Islands have low or no national fuel taxes. Looking at the revenue per liter in figure 7, all the countries but Iceland improve energy efficiency when optimizing the fishery.

Figure 7. Revenue from main species (EUR) per liter fuel

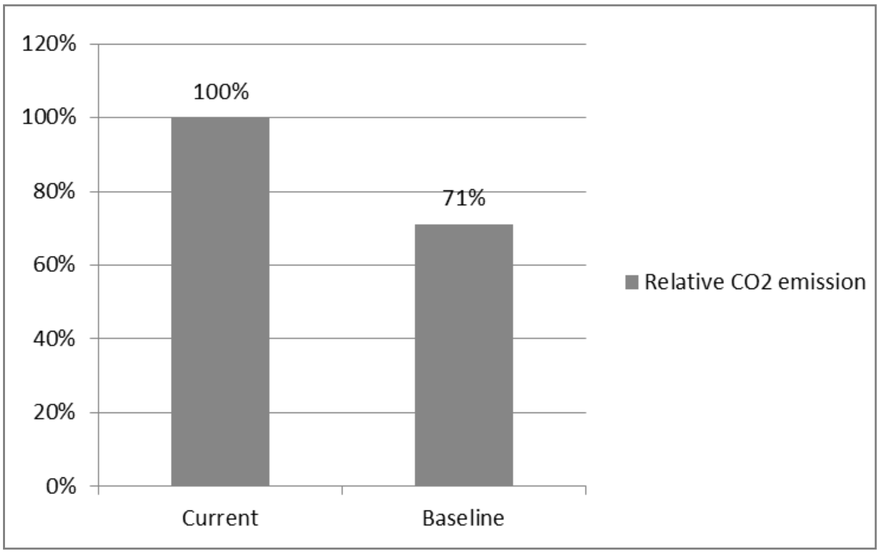


Compared to the baseline scenario, all the countries increase the value of landings per liter fuel in scenarios where fuel costs are higher. Intuitively, this is because, in optimal fisheries management the high costs must be covered by increased revenues for resource rent to be maximized, and thus the optimal level of effort and stock size will change.

6.2.4 CO_2 Emissions

The effects on CO_2 emissions are divided into two steps. The first is the reduction in CO_2 from optimizing the fishery, i.e. rebuilding fish stocks and adjusting the fleet to an economically optimal level. The second step is the effect found by introducing CO_2 costs in the fuel scenarios, which are then compared to the optimized fishery (baseline scenario). The effect of optimizing the fishery is presented in figure 8.

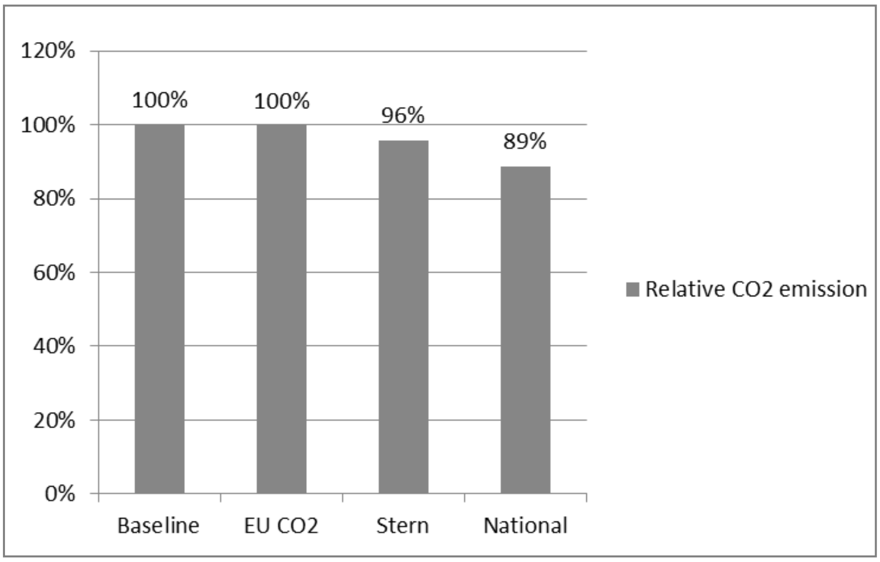
Figure 8. Reduction in CO₂ emissions from optimizing the fishery



The total CO_2 emissions are reduced by 29% in the optimized fishery compared to the emissions in current fisheries. Leaving Iceland out of the analysis, the corresponding figure is 48%. Iceland has a well developed management system with high efficiency (see table 7), and the potential for further efficiency gains is thus relatively limited.

Higher fuel costs are shown to reduce fuel consumption, and the effects on CO_2 emissions will follow from this. The CO_2 emission in the baseline scenario in figure 9 is set to one, and the other scenarios are compared to this. If Nordic fisheries buy emission allowances from the EU trading system, the total emission is expected to be reduced by 0.2%. Imposing the Stern cost on CO_2 emissions will lead to a reduction of 4.2%, and, imposing national taxation, a reduction of 11.3%. The national taxation differs widely among the Nordic countries, and for some the national taxation is very low, implying that their emissions will be higher in this scenario compared to the EU and Stern scenarios.

Figure 9. CO_2 emissions in fuel scenarios compared to baseline



6.2.5 Extension – the Greenlandic Processing Industry

For the Greenlandic shrimp fishery, the model results reveal that there are significant values to be gained by allowing quota trade between the in-shore and off-shore trawling vessels. In optimum 100% of the shrimp quota will be utilized by the off-shore segment. The off-shore segment processes 75% of the catch on-board, which is exported directly, while in-shore vessels land 100% in Greenland. Thus, supply to the land-based factories will fall considerably. Seen from a socio-economic point of view, the gain might be overestimated if losses appear in the domestic processing industry.

A full socio-economic analysis needs to take the economics of both vessels and land-based activities into account. That has not been done in the analysis above. Two fleet segments are compared at different stages in the value chain, and value added production is included in the profit of the production trawlers. The in-shore trawler segment does not have the same value added production, implying that the costs are mainly related to the fishery. To fully compare the two segments, it is more justifiable for the in-shore trawlers to include the value chain for the land-based production.

From appendix C2 it appears that, when including production in land-based factories, profit is not significantly changed for in-shore or for production trawlers. Thus, for the Greenlandic society, the gain of liberalizing domestic trade in shrimp quotas seems to hold when taking the potential effects of land-based factories into account. Such a conclusion needs to be confirmed in a full bio-economic analysis, identifying maximum resource rent and profit under the inclusion of the economics of both fishing vessels and activities in land-based factories. However, the situation for land-based factories in 2010 indicates that the estimated gain to the Greenlandic economy, from liberalizing the domestic shrimp quota trade, remains in an extended analysis.

7. Discussion

The overall pattern in the report is that changing from the current management to an optimal fisheries management has a substantially larger effect on the results than fuel taxes or CO_2 emission trading systems. Optimal management implies that the fleet size is set to an efficient level and that the stocks are rebuilt to maximize the economic performance of the sector (MEY). This would decrease the analyzed fishing fleet from 1,345 vessels to 737 vessels at the same time as improving economic performance by over 100% and reducing fuel consumption from 473 to 336 thousand m^3. Imposing fuel taxation corresponding to national fuel tax levels on the optimized fishery would imply a reduction of the fleet by approximately 80 vessels in total, and a reduction in fuel consumption of 39 thousand m^3. The effects are smaller in the other scenarios. The result that an increase in fuel prices only has a limited impact on fleet structure in an optimally managed fishery is supported by the European commission (2010), which finds fleet structure to be robust to a 50% increase in fuel price.

Many of the Nordic fisheries are far from optimally managed and some even have negative resource rents. Thus, there is considerable potential for increasing the economic contribution of fisheries to society. The estimation of potential resource rent in the report typically lies around 60–80% of landing value. This is in line with the findings in Asche *et al*. 2009, who estimated that the potential rent in Norwegian cod trawling was between 60 and 73% in 1997–98. As a comparison, the estimated resource rent in the Icelandic fishery, which is managed with Individual Transferable Quotas (ITQ) in this study, is 64%. Of course, the full economic potential of a fishery might not be obtainable in practical fisheries management for all countries, e.g. due to a broader set of political objectives than economic rents.

Turning to the socioeconomic part of the analysis, a first observation is that most of the countries will contain vessels using both active and passive gear in all scenarios. The exception is Greenland where only off-shore factory trawlers are maintained in the optimized fishery, and thus the employment opportunities in small-scale trawling will be lost. This is not compensated for by employment opportunities in the off-shore trawling fleet. Aggregated for all the Nordic countries, employment in the analyzed fisheries falls from about 6,800 to 4,200. It is possible to take socio-economic considerations into account in order to maintain employment in small-scale fisheries or rural areas, but this will always come at a cost due to reduced efficiency (Waldo and Paulrud, 2013). Social considerations might work with fuel taxes, but, as shown in the analysis where a Swedish quota was allocated to passive gear, this is efficient only to the extent that the small-scale fleet is viable enough to utilize the additional quota. When fuel costs became too high, the small-scale fishery became unprofitable and the quota un-utilized.

As pointed out in the introduction, active gear tends to be more fuel intense than using passive gear. A potential policy option for reducing CO_2 emissions would therefore be to allocate quotas to passive gear (see e.g. Driscoll and Tyedmers, 2010). However, from an economic perspective, this type of management action will be inefficient if trawling is efficient enough to pay the external costs for CO_2 and still be more profitable. In the analyzed fisheries, this tends to be the case, since a large share of trawling is also maintained under high fuel taxation scenarios.

Using the same technology as the present fishery, i.e. no investments in the development of gear are made, optimization of the fishery reduces total CO_2 emissions. It is reasonable to assume that higher fuel prices will lead to investments in less fuel-intense gear and engines. Such investments will reduce emissions further than estimated in the analysis. Moreover, it might affect the relative fuel intensity between trawlers and vessels using passive gear, and thus alter the impact of increased fuel prices on the fleet. If fuel bunkering in international waters without taxes is possible, the aggregate effect on both the fleet size and fuel consumption might be small, and if only larger vessels are able to reach international waters a national tax might change the fleet structure to the disadvantage of smaller vessels.

Fuel efficiency includes all species targeted by a fleet, i.e. no attempt is made to allocate resources to specific stocks or species, as is common in the literature (Ziegler and Hansson, 2003; Thrane 2004). Thus, when estimating catch/liter, this could either increase or decrease in the scenarios depending on reallocations among species. This reallocation occurs when optimizing the fishery with regard to stock and fleet sizes. When taking external CO_2 costs into account, both the catch and value per liter fuel increase.

From a policy perspective, rebuilding stocks and increasing fleet efficiency is an efficient management path to reducing the climate effects of fishing operations. Doing this will also have positive economic effects. Fuel taxes will have a positive effect on both fuel efficiency and CO_2

emissions, but to a lower extent. This is in line with the results in Ziegler and Hornborg (2013), who find that the fuel price has a limited role in fuel efficiency compared to stock development. However, improving stock status and reducing fleet size are known to be difficult to achieve in practical management. Many countries struggle with inefficient fleets and poor stock status despite long term objectives to rebuild stocks and adjust fleet capacity. In this analysis, Norway and Iceland have the highest value/liter fuel in the current management system, which is an expected result of efficient management. Interestingly, in optimal management the Norwegian fuel efficiency increases while Iceland is the only country where fuel efficiency decreases. This is due to Icelandic quotas being allocated to the large scale trawlers which are economically efficient but have low fuel efficiency. Also, the potential to improve fleet efficiency is limited in Iceland compared to the other countries, due to an already efficient management system. The example shows that even if improving stock status and fleet efficiency is an efficient policy for improving fuel efficiency in most cases, it is not necessarily so.

8. Conclusions

To get a fully efficient fishery, the management needs to address both society's cost for CO_2 emissions and the problem with fleet over capacity and stock size. Focus in this report is on CO_2 emissions, and currently the cost of using fuel in Nordic fisheries is lower than optimal from a climate perspective. The report analyses fuel taxes and emission trading systems as possible management instruments for reducing emissions. However, optimizing the fishery by stock recovery and reducing excess fleet capacity turned out to be an efficient instrument to both reduce the climate impact of the sector and improve the economic outcome. Introducing fuel taxes or an emission trading system in the optimized fishery will have small effects on CO_2 emissions, fleet size and employment opportunities. Thus, the well managed fishery is robust to changes in fuel prices and will be able to pay its external costs for CO_2 emissions. The increase in fuel efficiency is due to healthy stock levels and efficient fishing fleets, and is obtained without investments in new gear technology or management measures restricting fuel-intense fishing methods. However, the analysis also shows that an optimal fishery in some cases might imply increased use of fishing techniques with lower value per unit of fuel. This was the case for the Icelandic fishery, which is already managed with high efficiency.

9. Svensk sammanfattning

Bränsleanvändning i fisket står för ca 1,2 % av den globala oljeförbrukningen och resulterar i 130 miljoner ton CO_2-utsläpp årligen. Eftersom fisket är undantaget från bränsleskatter och befintliga handelssystem för CO_2-utsläppsrätter är incitamenten för att minska bränsleförbrukningen mindre än vad som är önskvärt ur ett klimatperspektiv. Detta resulterar i högre användning av bränsle än optimalt. Utsläppen påverkas även av fiskeripolitiska åtgärder som beståndens storlek och flottans effektivitet. I denna rapport används modeller som integrerar ekonomi och biologi för att analysera hur CO_2-utsläpp, flottans struktur, ekonomiskt resultat, och arbetstillfällen påverkas av en effektiv fiskeripolitik och av införandet av bränsleskatter alternativt handelssystem med utsläppsrätter i nordiskt fiske.

I rapporten analyseras fyra olika scenarier för att införa kostnader för CO_2-utsläpp i fisket. Det första scenariot i projektet är en ”baseline” där de befintliga skattelättnaderna på bränsle behålls men fiskbestånd och flotta förvaltas så att de genererar maximalt ekonomiskt utfall. I det andra scenariot (”EU”) antas fisket vara en del av EU:s system för handel med utsläppsrätter, och de extra kostnaderna för bränsle är alltså kostnaden för att köpa utsläppsrätter på marknaden. I det tredje scenariot (”Stern”) införs en skatt som motsvarar kostnaden för CO_2-utsläpp beräknat i Sternrapporten, och i det fjärde scenariot (”National”) beskattas bränsle på samma sätt för fiskare som för privatpersoner i respektive land.

För att få en representativ bild av det nordiska fisket, innehåller analysen fallstudier från alla nordiska länder: Sverige, Danmark, Norge, Island, Grönland, Färöarna och Finland. Alla uppgifter är från 2010. De 18 flottsegment som analyseras innehåller allt från kustnära småskaligt fiske efter lax i Finland med en total omsättning på ca 0,2 miljoner Euro till stora norska och isländska industritrålare med en total omsättning på mer än 325 miljoner Euro vardera. I analysen används tre modeller som alla är väl etablerade i litteraturen. De skiljer sig i hur de modellerar fisket i fråga om tidsram, samspel mellan fiske -och beståndsutveckling, m.m., och på så sätt bidrar de med olika dimensioner till analysen. Sammanlagt innehåller rapporten 7 länder, 18 flottsegment, 25 fiskbestånd, ett fullskaligt nationellt fiske (Sverige), samt en fördjupning av analysen där beredningsindustrin ingår (Grönland).

I dagens situation uppvisar flera av de analyserade fiskena ett negativt ekonomiskt resultat, och införs kostnader för utsläppsrätter eller bränsleskatter kommer dessa att ytterligare minska sin lönsamhet. Andra fisken är mer robusta för ökade bränslekostnader och kommer fortfarande att kunna generera intäkter till samhället. Om fisket förvaltas på ett ekonomiskt optimalt sätt ökar både lönsamhet och bränsleeffektivitet väsentligt jämfört med nuvarande förvaltningssystem. Optimal förvaltning innebär att bestånden är på en ekonomiskt optimal nivå och flottans kapacitet är anpassad till rådande fiskemöjligheter. *Detta skulle minska förbrukningen av bränsle från 473 till 336 tusen m*^{3} *(29 %)*, minska den analyserade fiskeflottan från 1 345 till 737 fartyg (45 %), och förbättra det ekonomiska resultatet med över 100 %.

Att introducera bränsleskatter eller ett system för utsläppshandel i ett optimalt förvaltat fiske kommer endast att få begränsade effekter på CO_2-utsläpp, flottans storlek, ekonomiskt resultat och sysselsättning. Exempelvis skulle en bränslebeskattning motsvarande den som gäller för privata konsumenters innebära en minskning av flottan med cirka 80 fartyg totalt, och en minskning av bränsleförbrukningen med 39 tusen m^3. Ett välskött fiske är med andra ord robust för förändringar i bränslepriser och fisket kommer att kunna betala de kostnader för CO_2-utsläpp som genereras.

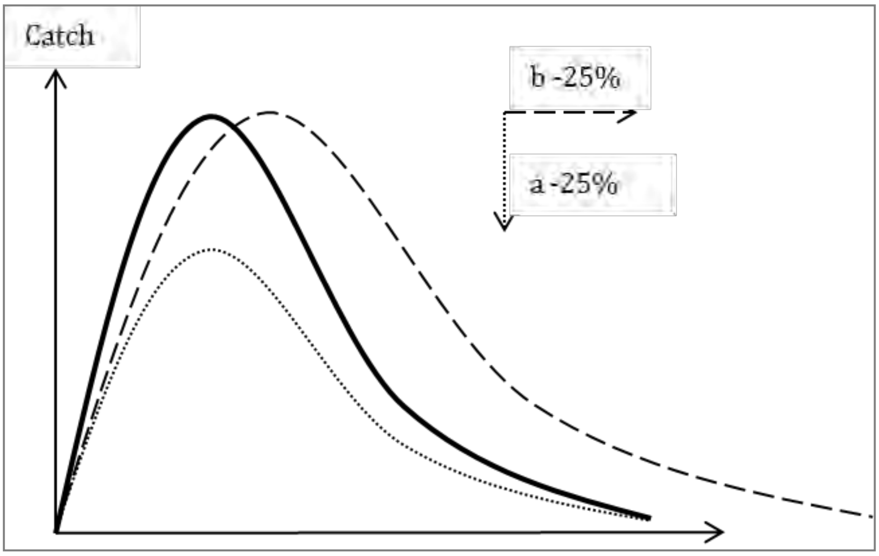
Ökningen av bränsleeffektivitet i optimal förvaltning beror på hållbara fiskbestånd och en fiskeflotta utan överkapacitet. Detta uppnås utan investeringar i nya redskap teknik eller förvaltningsåtgärder som begränsar bränsleintensiva fiskemetoder. Men analysen visar också att ett optimalt fiske i vissa fall kan innebära ökad användning av fiskemetoder med högre bränsleanvändning. Detta är fallet för det isländska fisket som redan drivs med hög effektivitet och där ytterligare effektiviseringar innebär lägre bränsleeffektivitet men ökat ekonomiskt överskott som täcker samhällets kostnader för CO_2-utsläpp.

Sammanfattningsvis visar analysen att en optimering av fisket genom ökade bestånd och minskad flotta är ett effektivt instrument för att både minska sektorns klimatpåverkan och förbättra det ekonomiska utfallet. Att introducera bränsleskatter eller ett system för utsläppshandel i ett optimerat fiske kommer att få små effekter på CO_2-utsläpp, flottstorlek och sysselsättning.

10. Appendix A. Sensitivity Analysis

In order to evaluate the sensitivity of the results with respect to the estimated relations between effort and catches, we perform a sensitivity analysis. Figure A1 shows how effort and catch are related in the model and how changes in two of the parameters, *a* and *b,* affect the model.

Figure A1. Relation between catch and effort



All catches in the model are sustainable in the sense that they show long run equilibrium, i.e. the catches can continue over the years. More effort implies more catches up to the MSY level where the sea cannot support higher stock growth. Further effort will decrease long-run catches. The thick line in the figure shows the estimated relation between effort and catch. If the stocks cannot support catches that are as high as estimated in the model, the relation will be the dotted line below the estimated line, which is obtained by reducing the value of parameter *a* (see model description in appendix B) by 25%. If more effort is needed to catch a specific amount of fish, the parameter *b* is reduced by 25%, and if less effort is needed, it is increased by 25%. The resulting fuel consumption is presented in table A1.

Table A1. Fuel consumption as share of current consumption for baseline scenario

Country	Current	Baseline	a-25%	b+25%	b-25%
Sweden	1	0.38	0.28	0.31	0.46
Denmark	1	0.38	0.36	0.37	0.42
Norway	1	0.51	0.36	0.45	0.59
Iceland	1	0.67	0.53	0.61	0.76
Greenland	1	0.69	0.59	0.63	0.78
Faroe Islands	1	0.37	0.33	0.31	0.46

The sensitivity analysis for *a* and *b* in table A1 refers to the baseline scenario. As presented in the report, fuel consumption is lower in the baseline scenario compared to the current situation. However, the magnitude of this varies with *a* and *b*. When the fishery is smaller (a-25%), or a low effort is necessary to catch the fish (b+25%), fuel consumption is lower. When higher effort is necessary to catch the fish (b-25%), fuel consumption is higher. However, in all cases the magnitude of the change is small, compared to the decrease in fuel consumption between the current fishery and the baseline scenario.

11. Appendix B. Bioeconomic Model

Appendix B contains the model used for Sweden, Denmark, Norway, Iceland, Faroe Islands, and Greenland. Throughout the appendix, resource rent calculations are used, but the model is equally valid for the profit case. The resource rent is identified for vessel group *j* in the current situation:

$$R_j{}^o = \sum_{i=1}^{n} Q_i{}^0 P_i{}^F + OT - TC_0 \qquad (1)$$

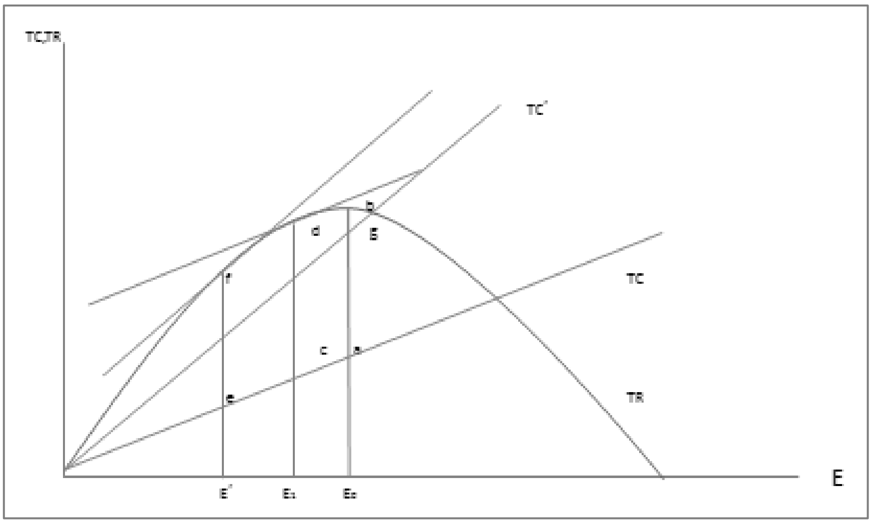
where:

- R_j^o is the current resource rent for vessel group *j*.
- Q_i^o is landings from stock *i.*
- *n* is the number of species.
- P_i^F is the first-hand price of landings from stock *i*.
- *OT* is other revenue.
- TC_o is total cost of labor and capital

Resource rent is identified on the basis of account statistics in a given period. Total costs are all considered variable, because we want to compare future situations in the long run. For comparison, fishing effort, catches and stocks must be in steady-state and markets for fish must be in equilibrium.

With respect to resource rent, wages of the crew in land-based industry and capital in other business are used to calculate costs. The remuneration of capital in other business corresponds to the interest on government bonds. Invested capital is measured by excluding the value of fishing rights, because value from selling fishing rights can be considered as a transfer. The resource rent in a single-species model is shown in Figure B1.

Figure B1: The resource rent in a single-species model



In Figure B1 total revenue, *TR*, and total opportunity costs, *TC*, in the baseline model are described for one vessel group. Assume that the initial situation is the effort level E_0. Now the initial resource rent is ab. The maximum resource rent is at E_1 with cd being the maximal resource rent. Assume now that the costs are shifted to *TC´* due to an increase in fuel costs. In this case the resource rent is bg. With this cost curve the maximal resource rent is ef with an effort level on *E´*.

In a multi-species fishery, which is the case for the analyzed fisheries, the maximum resource rent is identified by a simultaneous and equal change in effort for all stocks of a vessel group. Thereby, we assume that each vessel group´s relative time spent on various stocks is constant. The implication of this is that it is not possible to shift effort between stocks. The assumption is shown in Figure B2.

Figure B2: A multi-species fishery

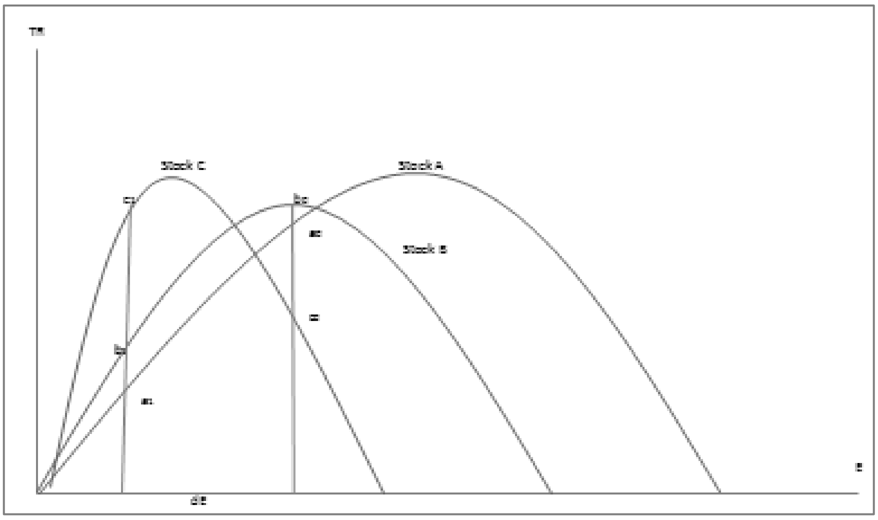


Figure B2 compares the current situation with a possible future situation for a reduction in effort for one vessel group. The maximum resource rent in a multi-species fishery is determined by changing the total effort. Because the relative effort used on each stock is constant, the change in effort is the same for each stock. TC is also changed given this assumption and, therefore, the maximum resource rent in a multi-species context is defined. Note that estimation results are based on a steady-state assumption corresponding to *TR* in Figure B1.

Following Figure B1, Figure B2 and Nielsen, Flaaten and Waldo (2012), the maximum resource rent is identified in three stages given the size of the resource rent in the current situation. In the first stage, the revenue is identified in (2)–(9) below on the basis of biological information. In the second stage, costs are identified in (10). In the third stage, the maximum resource rent is calculated in (11).

The total revenue (TR) for each vessel group, *j*, is given by:

$$TR_j = \sum_{i=1}^{n} Q_i {P_k}^F + OT \qquad (2)$$

where Q_i is the quantity of fish a vessel can harvest from a quota-controlled stock, given that the vessel group harvests a constant share of total catches of that stock. The assumption that each vessel group harvests a constant share of total catches implies that the harvest from a vessel not included in the analysis develops exactly like the harvest of a vessel included if they fish the same stocks. This assumption seems most reliable for stocks regulated with total quotas, as the majority of the stocks included in this report are. Stocks for which there is no available information are assumed to develop exactly like stocks where biological information exists. Note, also, that in (2) other revenue, OT, is assumed to follow effort.

The production function of fisheries can be expressed as:

$$Q_i = f(X_i(E_i)) \tag{3}$$

where:

- x_i is the biomass for stock i
- E_i is the total effort of all vessels fishing stock i.

The production function is such that the quantity of fish caught is a function of biomass, while biomass depends on total effort. As mentioned above, vessels in a certain group can harvest several stocks. However, it is assumed that the relative total effort directed at different stocks is constant. Note, also, that (4) is the total production function for all vessels fishing stock i. Thus, $\sum_{j=1}^{m} Q_{ij} = Q_i$ and $\sum_{j=1}^{m} E_j = E$, where m is vessel groups.

Define $G(X_i)$ as the natural growth of stock i and $\dot{X_i}$as the annual change in stock. Then, $\dot{X_i} = G(X_i) - Q_i$. Furthermore assume that a steady-state exists in the current situation such that $\dot{X_i} = 0$. The implication of this is that:

$$Q_i = G(X_i) \tag{4}$$

Thus, the natural growth of stock i, $G(x_i)$, equals harvest. The natural growth function is assumed to be of the Gompertz-Fox type:

$$G(X_i) = -rX_i \ln(\frac{X_i}{K}) \tag{5}$$

where r and K are parameters of the natural growth function. By using a Schaefer harvest function for vessel group j:

$$Q_i = \gamma E_j X_i \tag{6}$$

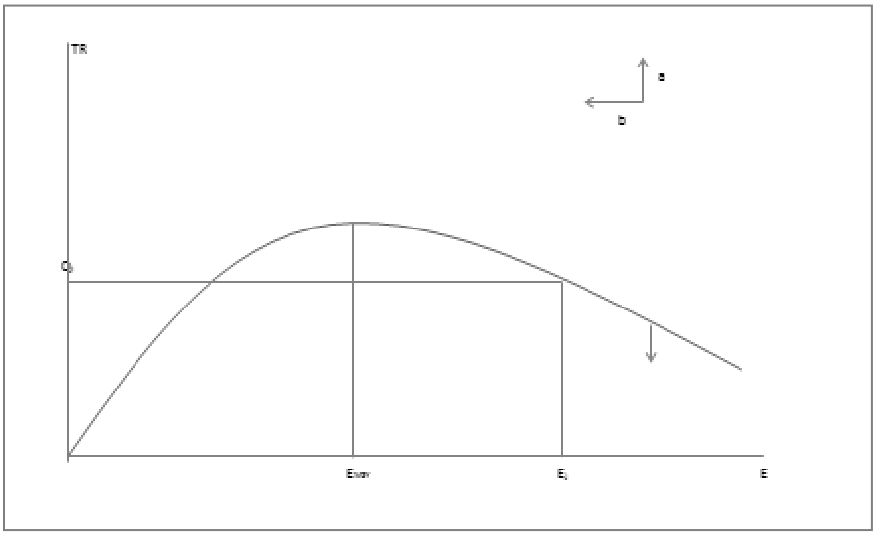
where γ is a constant catchability coefficient. Solving the Schaefer harvest function, substituting this solution into (5) and using (4) yield a sustainable yield function:

$$Q_i = aE_j e^{-(bE_j)} \tag{7}$$

The parameters $a = \gamma K$and b $= \gamma / r$ are calibrated for each stock. (7) corresponds to the case where a stock is shared by several vessel groups. With (7) a and b vary between groups due to differences in vessel harvest functions. This is due to the fact that we are interested in maximization of resource rent and profit. With this assumption, the aggregate harvest function arising from (7) becomes the sum of individual harvest functions.

The methodology for calibrating the sustainable yield function, (8), for each stock, *i*, exploited by each vessel group, *j*, is illustrated in Figure B3.

Figure B3: Method for calibration



The yield for stock *i* increases with effort until E_j^{MSY} and then falls approaching zero when effort goes towards infinity. The downward pointing arrow from the curve indicates that if the steady-state assumption currently does not hold, the identified curve overestimates sustainable yield, implying that the curve shifts downwards. In that situation the calculated maximum resource rent will be overestimated. Provided that the assumption of a steady-state holds, the maximum resource rent identified is reliable. The parameters a and b are identified knowing X_i corresponding to MSY for each stock and identifying E_j^{MSY} and E_j^0 and Q_i^0 (the current situation). As indicated by the arrows of a and b, b shifts the peak horizontally and is identified by an experiment where the peak is at E_j^{MSY}. It appears from (7) that the higher b, the more E_j^{MSY} shifts to the left (the direction of arrow b). The parameter a shifts the sustainable yield curve vertically, and is identified by an experiment in which the curve goes though (E_j^0, Q_i^0). It appears from (8) that the larger a, the larger Q_i for all E_j. Since calibration is undertaken on the basis of MSY, reliability of the model increases the closer exploitation in the considered fisheries is to MSY.[5]

The E_j^{MSY} for each stock is determined on the basis of the relation between X_i and E_j, specified assuming that the change in biomass depends on a change in the vessel group's effort. This relation appears when assuming that the vessel groups included in this report catch a fixed share of the stock in relation to the vessels which are not included, but which are fishing the same stocks. Thus, the relative stock levels are:

$$\frac{X_i^1}{X_i^0} = \frac{E_i^0}{E_i^1} \qquad (8)$$

where:

- E_j^0 and E_j^1 are the number of days spent fishing by vessel group j in the current and future period
- X^{i0} and X_i^1 are biomass in the current and future periods.

The functional form indicates that the trends in biomass are determined by changes in effort given the biomass and effort in the current situation. (9) specifies that when the effort of vessel group j, as well as total effort, changes by a certain percentage, the biomass of stock i changes by the same percentage in the opposite direction.

Finally, it is assumed that the vessel group´s relative time spent on different stocks in a future situation will be the same as in the current situation:

$$\frac{E_{ij}^1}{\sum_{i=1}^{n} E_{ij}^1} = \frac{E_{ij}^0}{\sum_{i=0}^{n} E_{ij}^0} \qquad (9)$$

where E_{ij}^0 and E_{ij}^1 are days at sea spent on stock i of vessel group j in the current and future situations. Assuming (10), Q_i in (7) can be inserted into (2) provided that $E > 0$, and in this way the vessel group´s total revenue in a future situation is found.

Since calculations are made for the long run, all costs are variable and the cost function for vessel group j in a future situation under the assumption of constant factor prices is:

---

[5] For a detailed review of the calibration method see Nielsen, Flaaten and Waldo (2012).

$$TC_j{}^1 = TC_j{}^0 (\frac{E_{ij}{}^1}{E_{ij}{}^o})^{(1+v)} \qquad (10)$$

The cost function of future situations is calculated on the basis of the present cost adjusted for the change in effort within a vessel group. v is a parameter describing the difference in fishing efficiency brought about by using input factors. When $v > 0$ some fishermen have higher levels of skill than others, causing infra-marginal rents. In this article we assume that $v = 0.33$. However, we assume that the cost per day at sea is constant. $TC_j{}^0$ and $TC_j{}^1$ include costs for fuel.

Resource rent is determined in a new situation for a vessel group in total, since it does not make sense to identify resource rents for each group when they fish shared stocks. Total resource rent for all *m* vessel groups in the new situation ($\sum_{j=1}^{m} R_j{}^1$) is:

$$\sum_{j=1}^{m} R_j{}^1 = \sum_{j=1}^{m}(\sum_{i=1}^{n}(a\frac{X_i{}^0 E_j{}^0}{E_j{}^1} e^{-\frac{bX_i{}^0 E_j{}^0}{E_j{}^1}})(P_i{}^F \sum_{i=1}^{N}(a\frac{X_i{}^0 E_j{}^0}{E_j{}^1} e^{-b\frac{X_i{}^0 E_j{}^0}{E_j{}^1}}))) + OT - TC_j{}^0 (\frac{E_{ij}{}^1}{E_{ij}{}^o})^{(1+v)} \qquad (11)$$

The total resource rent is found as the sum of the individual rents of each of the *m* vessel groups, and is the difference between total revenue and total costs.[6] (11) shows the total revenue minus the total cost. Total effort for all *m* vessel groups for all *n* stocks in the new situation is the only part determined by maximization. There is no single analytic solution since the second term on the right-hand-side may have several solutions with E_1 raised to *(1 +v)* power. This implies that (11) must be solved numerically by calibrating the parameters in a first step and, based on this, maximizing with respect to E_1 in the second step. Based on (11), maximization can be accomplished.

The total resource rent can be maximized given that vessels can freely allocate quotas to each other:

$$\underset{E_j^1}{\text{Max}}(\sum_{j=1}^{M} R_j{}^1) \qquad (12)$$

---

[6] See Nielsen, Flaaten and Waldo (2012) for calculations.

(12) implies that the sum of resource rents in all vessel groups is maximized. (12) is identified by inserting (12) where effort for the m vessel groups in the new situation is the control variable. For every total effort the total resource is maximized by reallocating effort among the m vessel groups. Thereby, for every total effort, a new allocation of effort between groups of vessels appears for which the maximum resource rent is identified by (11). For all $E_1 = \sum_{j=1}^{m} E_j{}^1$ the m effort levels are determined using the Solver function in Excel. In a second step, the total resource rent is maximized by choosing among all the total numbers of effort that have the optimal allocation. Resource rents are found based on the optimal $E_j{}^1$.

We also define the gain in resource rent while holding total effort constant and redistributing effort among vessel groups. The maximization problem may be stated as:

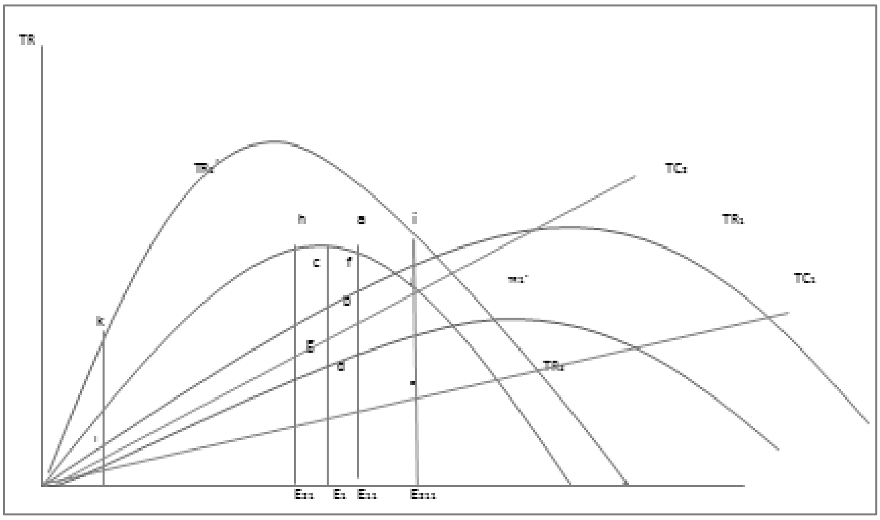
$$\text{Max}(\textstyle\sum_{j=1}^{M} R_j{}^1) \qquad (13)$$

s.t.

$$\textstyle\sum_{j=1}^{n} E_j{}^1 \leq E^1 \qquad (14)$$

where E^1 is the constant total effort. With (13) and (14) we redistribute effort until the marginal resource rent in the various vessel groups is identical. This redistribution will yield an optimum and is illustrated in Figure B4.

Figure B4: Redistribution of effort



In Figure B4 TR1 and TC1 are the total revenue and total cost for vessel group 1. The total revenue and total cost for vessel group 2 are TR2 and TC2. Assume that total effort is E1 for both vessel groups 1 and 2. The marginal resource rent is cd for vessel group 1 and ab for vessel group 2. The marginal resource rent is larger for vessel group 2 than for vessel group 1. Now, we allow for redistribution of effort. The optimum will be where the total effort is the same and the marginal resource rent is the same for both vessel groups. This will occur at E11 and E21 where the marginal resource rent is identical (ef = hg). Thus, E11 and E21 secure a social optimum. However, the total revenue will also shift upwards and downwards due to reallocation of quotas. The new revenue curves are TC2´ and TC1´. The optimum is still where the marginal resource rent is identical. This occurs at E111 and E211 where ij = kl.

The identified maximum resource rent can be both underestimated and overestimated. It is assumed that the relative effort on each stock is constant for every vessel group. This implies that vessels cannot adapt optimally, which leads to underestimation. Moreover, only average vessels in each group are considered. This leads to the result that only a few vessel groups remain active. This is not realistic because the most efficient vessels in each group will remain active. Thus, the maximum resource rent is underestimated. On the other hand, the maximum resource rent can be overestimated if fisheries are not in steady-state.

12. Appendix C. National Reports

C1. Sweden

Cecilia Hammarlund, AgriFood Economics Centre, Lund University
Staffan Waldo, AgriFood Economics Centre, SLU

C1.1 Introduction

The purpose of this study is to assess the effects of imposing fuel taxes on the Swedish Baltic demersal fishery. We have selected four segments that cover 85 percent of the Swedish cod fishery. The segments are demersal trawlers of three different sizes (24–40 m, 18–24 m and 12–18 m), and one segment with vessels using passive gear (10–12 m). The effects of fuel taxes are analyzed in a modeling framework (section C1.4) by using four scenarios for different fuel costs. The scenarios are presented in section C1.2, and data for Swedish fuel taxes in section C1.3. The results are presented in section C1.5.

C1.2 Scenarios

The analysis is performed in four scenarios based on different fuel costs. These are compared to the current situation in the fishery. The first scenario is an optimization of the model without fuel taxes, the second scenario introduces the Swedish fuel taxes, the third scenario assumes that fishermen will have to buy CO_2 emission rights in the EU market, and the fourth scenario assumes additional fuel costs as calculated in the Stern report. The scenarios are summarized in Table C1.1. The CO_2 prices added to the price of fuel are further discussed in section C1.3.

Table C1.1: Scenarios used in the study

Scenario	Definition	Swedish case Euro / m^3 diesel added to fuel price
0. Current situation	Statistics (Fleet and economic)	0
1. Benchmark	Model run with no taxes	0
2. National taxes	Energy tax and CO2 tax	EUR 421.85
3. EEX EU emission allowances	Only CO2 costs	EUR 34.01 (same for all countries)
4. Stern	Only CO2 costs	EUR 159.02 (same for all countries)

C1.3 Data

C1.3.1 Swedish Fuel Taxes

In Sweden all vessels, including fishing vessels, are exempt from fuel tax. Fuel tax consists of carbon dioxide tax and energy tax. Energy tax is levied on diesel oil, which is the type of fuel used by Swedish fishing vessels, at four different levels depending on environmental impact. Fuel with the highest environmental impact, class 3, is taxed at SEK 2.17 per liter. Class 2 fuel is taxed at SEK 2.03 per liter and class 1 fuel, which has the smallest environmental impact, is taxed at SEK 1.76 per liter. There is also a so-called green-colored diesel with lower energy tax, at SEK 0, 82 per liter. The use of this kind of diesel requires a special permit (Swedish Tax Authority 2013). Most vessels use class 1 to class 3 diesel (Swedish Board of Fisheries 2007). Carbon dioxide tax is the same for all types of fuel and, since the first of January 2013, the carbon dioxide tax has been SEK 3.09 per liter (Swedish Tax Agency 2013). Fuel taxes as reported by the Swedish Tax Authority in 2010 are used in this study. The CO_2 costs are presented in Table C1.2.

Table C1.2: Swedish CO_2 and energy taxes, EU quota prices and Stern estimate

	EUR/tonne CO2	EUR/m^3 fuel
Swedish energy tax 2010	76.34	190.85
Swedish CO2 tax 2010	133.59	333.98
EU CO2 quota price 2009	13.6	34.01
Stern (2006)	63.60	159.02

Source: Stern (2006) and the Swedish Tax Authority (2010).

The Swedish CO_2 -tax is considerably higher than the Swedish energy tax, and both of these taxes are much higher than the EU quota prices. Using the Stern estimated quota price will give higher fuel prices than the current EU quota price, but considerably lower prices than if Swedish fuel taxes are introduced.

C1.3.2 Economic Data

Physical and economic data for the fisheries in this study are presented in Table C1.3 below. The largest segment in terms of number of employees is the medium demersal trawler segment (DTS 18–24 m), which had an equivalent of 79 full-time workers in 2010. There are 55 vessels using passive gear (PAS 10–12 m) and 57 demersal trawlers (DTS 12–18 m, DTS 18–24 m and DTS 24–40 m). The value of physical assets is larger for the two largest trawler segments (DTS 18–24 m and DTS 24–40 m).

The number of days-at-sea per vessel in Table C1.3 shows that, on average, Swedish demersal vessels fish 90–110 days per year, and that medium demersal trawlers (DTS 18–24 m) are out of harbor more often than vessels in other segments. Turning to fuel consumption, larger demersal trawlers, as expected, use much more fuel than smaller demersal trawlers and vessels using passive gear. The larger demersal trawlers (DTS 24–40 m) use almost as much fuel as the medium demersal trawlers (DTS 18–24 m), although there are only 13 larger trawlers compared to 29 medium trawlers.

Table C1.3: Physical and economic data for the Swedish Baltic Demersal Fishery

	PAS 10–12 m	**DTS 12–18 m**	**DTS 18–24 m**	**DTS 24–40 m**
Physical data				
Full-time employment	36	23	79	28
Number of vessels	55	15	29	13
Physical assets (EUR Million)	1.7	1.2	4.0	9.3
No. of days at sea per vessel	96	91	109	97
Fuel consumption (m^3)	951	756	4,108	3,889
Share of total landings of cod in Sweden	9%	12%	39%	24%
Main stocks*	Cod 22–24	Cod 22–24	Cod 22–24	Cod 22–24
	Cod 25–29+32	Cod 25–29+32	Cod 25–29+32	Cod 25–29+32
	Herring 3A+22–24	Sprat 22–32	Sprat 22–32	Sprat 22–32
	Herring 30	Herring 25–32	Herring 3A+22–24	Herring 3A+22–24
		Herring 30	Herring 25–32	Herring 25–32
			Herring 30	Herring 30
Share of main stocks of value of landings (%)	75%	87%	74%	80%
Account data (EUR Million/year)				
Turnover	2.3	3.0	11.1	6.5
Fuel costs	0.6	0.5	2.3	2.1
Salary	1.5	1.0	3.3	1.2
Other operating costs	0.8	0.6	4.1	2.7
Capital costs	0.3	0.2	0.7	1.1
Depreciation	0.6	0.3	1.0	2.1
Salary per FTE (EUR/year)	5,293	12,629	30,975	35,485
Opportunity costs				
Salary per FTE (EUR/year)	41,184	41,184	41,184	41,184
Capital (%)	6	6	6	6

*Stocks are defined by their FAO Codes. A segment must fish more than 1,000 kilos of a stock to be included in the model.

Source: Swedish Agency for Marine and Water Management.

Looking at the account data, it is apparent that medium demersal trawlers (18–24 m) have the largest turnover, followed by the larger demersal trawlers (24–40 m). Smaller demersal trawlers (12–18 m) and vessels using passive gear have smaller turnover. Costs are also higher for the two largest demersal segments with other operating costs being particularly high. Other operating costs are the sum of “cost of maintenance and repairs” plus “other variable costs” as defined by the European Commission Data Dollection Framework (DCF). Salary per full-time equivalent is considerably lower for the passive gear segment than for other segments; for example, the reported wage is six times larger for the largest trawler segment (DTS 24–40 m). In addition, salary per full-time equivalent for the smallest trawler segment (DTS 12–18 m) is only one third of the salary of the larger trawler segment (DTS 24–40 m). As discussed below, this will have implications for the profit-maximizing scenarios, when compared to the resource-rent scenarios where opportunity wages rather than actual wages are used. The opportunity wage is assumed to be the wage of a packager or factory worker, which was 19.80 euro per hour in 2010 (including social security payments)(SCB 2013). The opportunity interest rate is assumed to be 6 percent.

C1.3.3 Biological Data

Larger demersal trawlers (DTS 24–40 m and DTS 18–24 m) fish all stocks that are represented in the study (which are the commercially most important fish stocks in the Baltic), i.e. cod in the Western Baltic (Area 22–24) and Eastern Baltic (Area 25–32), sprat in the entire Baltic Sea (Area 22–32), herring in the Western Baltic (Area 3A and 22–24), herring in the Eastern Baltic (Area 25–32) and herring in the Bothnian Sea (Area 30). Smaller demersal trawlers (DTS 12–18 m) fish all stocks except herring in area 3A, 22–24. Vessels using passive gear fish all stocks except the sprat stock and the herring stock in area 25–32. For all segments fishing the stocks presented in Table C1.3, these stocks represent the main part of the economic value of the fisheries.

The vessel segments used in this study cover 85 percent of the Swedish cod fishery, while the pelagic fleet not included in this study is the most important fleet for herring and sprat. The vessel segments’ importance for the Swedish Baltic cod fishery is presented in more detail in Table C1.4.

Table C1.4: Presentation of segments used in the study

Code	Definition	Value of landings of cod, million euro in 2010	Share of the value of total landings of cod
PAS 10–12 m	Drift and/or fixed netters with a vessel length between 10 and 12 m.	1.51	0.09
DTS 12–18 m	Demersal trawlers and/or demersal seiners with a vessel length between 12 and 18 m.	2.00	0.12
DTS 18–24 m	Demersal trawlers and/or demersal seiners with a vessel length between 18 and 24 m.	6.23	0.39
DTS 24–40 m	Demersal trawlers and/or demersal seiners with a vessel length between 24 and 40 m.	3.81	0.24
Total landings of cod by the segments included in the study		13.55	0.85
Total landings of cod in Sweden		16.03	1.00

Demersal trawlers catch 75 percent of the cod with vessels of medium size (18–24 m) being the largest segment. Vessels using passive gear (drift and fixed netters) catch 9 percent of the value of Swedish cod landings.

The biological data used in this study is from ICES (International Council for the Exploration of the Sea) and is presented in Table C1.5. The latest available estimates of stocks in 2010 are used for the assessment of SSB today. For the assessment of SSBmax, Bpa is used as a first choice and MSY btrigger as a second choice, and, when there is no estimate for the MSY spawning mass, the forecast of the latest available year (i.e. 2014) is chosen. Bpa is a precautionary reference point for spawning stock biomass (SSB) and MSY btrigger is a biomass reference point that triggers a cautious response within the ICES MSY framework (ICES Advice 2012, Book 1). The table also gives information on whether fishing mortality is above target, appropriate or below target in each stock.

Table C1.5: Actual spawning stock biomass and spawning stock which offer the largest renewable catches

Species	Area	SSBtoday (latest assessment of 2010)	Source	SSBmax	Source	Fishing mortality compared to MSY-level
Cod	22–24	30,001	ICES Advice 2012, Book 8, Table 8.4.1.3	23,000	ICES Advice 2012, Book 8, p. 7, Bpa	Above target
Cod	25–32	208,152	ICES Advice 2012, Book 8, Table 8.4.2.3	239,000	ICES Advice 2012, Book 8, p.18, precautionary approach SSB (2014)	Appropriate
Sprat	Baltic Sea	1,061,000	ICES Advice 2012, Book 8, Table 8.4.8.4	751,000	ICES Advice 2012, Book 8, p.56, precautionary approach SSB (2014)	Below target
Herring	22–24, IIIa	108,427	ICES Advice 2012, Book 6, Table 6.4.15.3	110,000	ICES Advice 2012, Book 6, p.268, MSY btrigger	Appropriate
Herring	25–29, 32 excluding the bay of Riga	631,782	ICES Advice 2012, Book 8, Table 8.4.4.3	645,000	ICES Advice 2012, Book 8, p.30, SSB (2014) using the precautionary approach	Above target
Herring	30	551,281	ICES Advice 2012, Book 8, Table 8.4.6.3	271,000	ICES Advice 2012, Book 8, p.49, MSY btrigger	Appropriate

Fishing mortality is above target for cod in the Western Baltic (Area 22–24) and for herring in the Eastern Baltic (Area 25–29 and 32). Using the precautionary approach, the spawning stock biomass of cod in the Western Baltic should not be below 23,000 in order not to risk the productivity of the stock. The SSB of herring in the Eastern Baltic is almost at the predicted level of SSBmax, meaning that the current stock level should be kept in order not to risk lower productivity. For the remaining stocks, fishing mortality compared to MSY level is appropriate (Cod in Area 25–32, Herring in Area 22–24, IIIa and Herring in Area 30) or even below target (Baltic sprat stock). SSBs for the cod stock and the herring stock in the Eastern Baltic are expected to increase in the future using the precautionary approach. The herring stock in the Bothnian Sea (Area 30) and the Baltic sprat stock are expected to decrease.

C1.4 Results

The result section starts with a presentation of the current situation, and profits and resource rent with fuel taxes without any maximizations. Next, the estimations of the parameters in the production functions are described, and the results from the model optimization for each of the scenarios are presented.

C1.4.1 The current situation

Introducing fuel taxes in the current situation, and assuming that fishers do not profit maximize or change their choice of inputs or outputs in any way, would result in a large decrease of an already negative total profit for the segments in the study. The only segment that would still generate a positive profit under national fuel taxes is the small trawler segment (DTS 12–18 m). Introducing EU CO_2 taxes, which are rather small, would keep small trawlers and medium trawlers (DTS 18–24 m) profitable. The Stern tax, which is set at a level between the EU tax and the national tax, is large enough to make small trawlers as well as medium trawlers unprofitable.

Table C1.6: Introducing fuel taxes in the current situation

	Current profit				Current resource rent			
	No fuel tax	National fuel taxes imposed	EU CO_2 tax imposed	Stern tax imposed	No fuel tax	National fuel taxes imposed	EU CO_2 tax imposed	Stern tax imposed
DTS 24–40 m	-2.60	-4.64	-2.93	-4.15	-3.26	-5.30	-3.59	-4.80
DTS 18–24 m	0.55	-1.60	0.20	-1.08	-0.46	-2.62	-0.81	-2.10
DTS 12–18 m	1.06	0.66	0.99	0.76	0.33	-0.07	0.26	0.03
PAS 10–12 m	-0.21	-0.71	-0.29	-0.59	-1.59	-2.08	-1.67	-1.96
Total	-1.20	-6.30	-2.03	-5.06	-4.98	-10.07	-5.80	-8.84

Resource rent calculations of the current situation show similar effects of introducing fuel taxes, although now all segments have a negative resource rent when national taxes are introduced. The only profitable segment in the current situation is the smaller trawler segment (12–18 m). The reason for the difference between profit and resource rent calculations is that wages that are used when calculating profits are lower than the opportunity wages used when calculating resource rent.

C1.4.2 Estimation of the parameters in the production function

The production function used in this study is:

$$Q = aEe^{-bE}$$

where Q is landings, E is effort and e is the natural number. The parameters *a* and *b* are calibrated using the information given in Table C1.5 and the current landings and effort of each fleet segment.

The parameter values of the production functions are shown in Table C1.7. Parameter *a* shifts the function up and down depending on the size of the landings. Parameter *a* is high, e.g. for cod in the Eastern Baltic (Area 25–29 and 32), for all segments since this is fishery stock with high catch volumes. Trawler segments (DTS 24–40, DTS 18–24 and DTS 12–18) also have high parameter *a*-values for sprat since this is an important stock in terms of weight, while the passive segment has no parameter for sprat since it does not target the species.

Table C1.7: Calibrated parameter values of the production function

	DTS 24–40m	DTS 18–24m	DTS 12–18m	PAS 10–12m
Parameter a				
Cod 22–24	163	179	205	213
Cod 25–29+32	6,110	4,139	3,250	314
Sprat 22–32	4,251	3,052	3,051	.
Herring 3A+22–24	2,333	707	.	248
Herring 25–32	3,678	2,994	2,630	.
Herring 30	944	68	206	18
Parameter b				
Cod 22–24	0.6	0.2	0.6	0.1
Cod 25–29+32	1.0	0.4	0.9	0.2
Sprat 22–32	0.6	0.2	0.5	.
Herring 3A+22–24	0.8	0.3	.	0.2
Herring 25–32	0.8	0.3	0.7	.
Herring 30	0.4	0.2	0.4	0.1

The value of the *b*-parameter varies with the curvature of the production function. A higher value indicates that landings are changing faster with increasing effort. After a maximum has been reached, an increase in effort by large trawlers (DTS 24–40 m) and small trawlers (DTS 12–18 m) decreases landings to a larger extent than the same increase of effort in other segments. An increase in effort by medium sized trawlers (DTS 18–24 m) affects the volume of landings less than an increase in effort by other trawler segments. Increased effort by vessels using passive gear (PAS 10–12 m) affects the volume of landings less than increased effort by trawlers.

C1.4.3 Profit maximization results

Tables C1.8, C1.9, C1.10 and C1.11 show results from the model. The first column in Table C1.8 shows the current situation where the demersal fishery as a total has a negative profit, and large demersal trawlers (24–40 m) make the greatest losses. Smaller and medium trawlers (12–18 m and 18–24 m) are profitable in the current situation whereas vessels using passive gear (10–12 m) are unprofitable. Under profit maximization, the largest demersal trawlers (24–40 m) will exit the fishery and the remaining segments will all be profitable. Fishing will be concentrated to medium demersal trawlers (18–24 m) and vessels using passive gear (10–12 m). The medium sized demersal trawlers (18–24 m) will have a substantial increase in profit, increasing from 0.55 million euro to 7.99 million euro.

The number of vessels will decrease dramatically when profit is maximized, in total from 112 to 51. Effort changes in all segments will be large; by using half of the days used today the fishing segments would be profitable in the long run. Fuel consumption, CO_2 -emissions and employment will be concentrated to the medium trawler segment (18–24 m) and the passive gear segment (10–12 m). Employment changes will not be as drastic in these two segments as in other segments.

Introducing national fuel taxes in the profit maximizing situation (scenario 2) would, as expected, reduce profits as compared to the maximizing profit scenario (scenario 1). Fuel consumption and CO_2 emissions would decrease further, as would the number of vessels and the number of employees. Although there will still be a concentration to medium demersal trawlers (DTS 18–24 m) and vessels using passive gear (PAS 10–12 m), this concentration will be somewhat less intense in scenario 2.

Table C1.8: Long run effects of fuel taxes on *profit*; number of vessels, effort, fuel consumption, CO_2 emissions and employment

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Profit, EUR Million					
DTS 24–40 m	-2.61	0.00	0.00	0.00	0.00
DTS 18–24 m	0.55	7.99	6.43	7.74	6.77
DTS 12–18 m	1.06	0.23	0.48	0.26	0.43
PAS 10–12 m	-0.21	2.40	2.07	2.32	2.15
TOTAL	-1.20	10.62	8.98	10.32	9.35
Number of vessels					
DTS 24–40 m	13	0	0	0	0
DTS 18–24 m	29	22	18	22	19
DTS 12–18 m	15	1	2	1	2
PAS 10–12 m	55	28	24	29	25
TOTAL	112	51	44	52	45
Effort change					
DTS 24–40 m		-100%	-100%	-100%	-100%
DTS 18–24 m		-25%	-39%	-26%	-36%
DTS 12–18 m		-93%	-85%	-92%	-87%
PAS 10–12 m		-43%	-50%	-40%	-49%
TOTAL		-50%	-57%	-49%	-56%
Fuel consumption, m^3					
DTS 24–40 m	3,889	0	0	0	0
DTS 18–24 m	4,108	3,083	2,510	3,046	2,627
DTS 12–18 m	756	54	114	64	101
PAS 10–12 m	951	543	471	568	481
TOTAL	9,705	3,681	3,096	3,679	3,209
CO2 emissions					
DTS 24–40 m	9,723	0	0	0	0
DTS 18–24 m	10,270	7,708	6,276	7,615	6,568
DTS 12–18 m	1,891	136	285	161	252
PAS 10–12 m	2,378	1,358	1,178	1,421	1,203
TOTAL	24,262	9,202	7,740	9,197	8,023
Employment, full-time equivalents					
DTS 24–40 m	28	0	0	0	0
DTS 18–24 m	79	60	48	59	51
DTS 12–18 m	23	2	4	2	3
PAS 10–12 m	36	34	30	36	30
TOTAL	167	95	82	97	84

Table C1.8 also compares the removal of national exemptions with the introduction of EU CO_2 -quota prices and Stern quota prices (i.e. scenario 3 and 4). The EU CO_2 -quota price is rather low, equivalent to EUR0.034 per liter of fuel used, and hence scenario 3 results are close to scenario 1 results. The quota price suggested in the Stern report (scenario 4) is equivalent to an increase of the fuel price to 0.159 per liter of fuel used, and thus scenario 4 implies more drastic changes than scenario 3, but less drastic changes then scenario 2, the national taxes scenario. This pattern reappears in Tables 9, 10 and 11.

Table C1.9 shows the effects on profit revenue per liter, value of landings, landed volume, days-at-sea and volume per day-at-sea for the current situation and the four profit maximizing scenarios. Revenue per liter used increases when fishers are profit maximizing, and increases even further when fuel taxes are introduced. This indicates that vessels would be more efficient in their use of fuel if the total profit in the sector was maximized and if fuel taxes were introduced.

Table C1.9: Long run effects of fuel taxes on *profit*; revenue per liter, value of landings, landed volume, days-at-sea and volume per day-at-sea

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO$_2$ quota price	4. Stern quota price
Revenue per liter used, EUR					
DTS 24–40 m	1.67	0.00	0.00	0.00	0.00
DTS 18–24 m	2.71	3.75	4.00	3.76	3.95
DTS 12–18 m	3.97	5.77	6.10	5.73	6.04
PAS 10–12 m	2.42	3.43	3.65	3.36	3.62
TOTAL	2.36	3.73	4.03	3.73	3.97
Value of landings, million EUR					
DTS 24–40 m	6.50	0.00	0.00	0.00	0.00
DTS 18–24 m	11.14	11.57	10.05	11.46	10.38
DTS 12–18 m	3.00	0.31	0.70	0.37	0.61
PAS 10–12 m	2.30	1.86	1.72	1.91	1.74
TOTAL	22.95	13.74	12.46	13.73	12.73
Volume (1,000 tonnes) of main species					
DTS 24–40 m	17.0	0.0	0.0	0.0	0.0
DTS 18–24 m	26.8	17.5	15.1	17.3	15.6
DTS 12–18 m	10.1	0.6	1.2	0.7	1.1
PAS 10–12 m	3.2	1.7	1.6	1.8	1.6
TOTAL	57.1	19.8	17.9	19.8	18.3
Days-at sea					
DTS 24–40 m	1,256	0	0	0	0
DTS 18–24 m	3,168	2,378	1,936	2,349	2,026
DTS 12–18 m	1,370	98	206	116	183
PAS 10–12 m	5,306	3,031	2,630	3,171	2,685
TOTAL	11,100	5,507	4,772	5,636	4,893
Volume (tonnes of main species) per day at sea					
DTS 24–40 m	13.6	0.0	0.0	0.0	0.0
DTS 18–24 m	8.5	7.4	7.8	7.4	7.7
DTS 12–18 m	7.4	5.7	6.0	5.7	6.0
PAS 10–12 m	0.6	0.6	0.6	0.6	0.6
TOTAL	5.1	3.6	3.8	3.5	3.7

The value of landings is calculated as prices in the current situation times the volume of landings in each scenario. Since the volume of landings decreases drastically when profit maximizing, the value of landings is considerably less in the profit maximizing scenarios than in the current situation. Fishing less gives a higher profit, something that is likely when effort in the current situation is larger than in the optimal situation, and costs are high. Effort can be seen to be decreasing in Table C1.9 as the number of days at sea is halved when the profit making scenario is compared to the current situation.

The last rows of Table C1.9 show the volume caught per day at sea by each segment. Comparing the current situation with the profit maximizing scenario (scenario 1) shows that less is fished per day-at-sea, which is perhaps a bit surprising since vessels now are expected to fish more efficiently. This can be explained by a reduction in caught volumes of sprat, which is a species with low value and high volumes. In the second scenario, however, we have the expected increase in efficiency; the volume per day-at-sea increase when national fuel taxes are introduced in a profit maximizing fishery (i.e. scenario 1).

C1.4.4 Resource rent results

Next, we turn to the long-run effects of fuel taxes on resource rent (Table C1.10 and Table C1.11). Instead of using actual wages and interest payments, opportunity wages and opportunity capital costs are now used (as described above). The resource rent is lower than profit in all scenarios. The difference is quite large, which is related to the difference in actual and opportunity costs of wages and capital, which are substantial in Sweden. In the current situation all segments except the small trawlers (DTS 12–18 m), have a negative resource rent. The largest trawlers (DTS 24–40 m) have the lowest resource rent.

Table C1.11 shows that the current negative resource rent turns into a positive resource rent when maximizing (scenario 1). Just like in the profit maximizing scenarios, a concentration to medium demersal trawlers (DTS 18–24 m) and medium vessels using passive gear (PAS 10–12 m) is visible in the resource rent maximizing scenarios. As in the profit maximizing scenarios, the largest demersal trawlers (DTS 24–40 m) exit the fishery. The major difference between profit maximizing and resource rent maximizing is that vessels using passive gear (PAS 10–12 m) do not gain as much in the resource rent scenarios. This is related to the low wages reported by the segments that are used in the profit scenarios. Since the resource rent scenarios do not have different opportunity wage costs per full time equivalent for different segments, the passive gear segment has relatively higher costs in the resource rent scenarios compared to the profit scenarios. This is also reflected in the reduction of effort, the number of vessels etc. for the passive gear segment. For example, the number of full-time employees in the passive gear segment is 23 in the resource rent maximizing scenario, compared to 43 in the profit maximizing scenario.

Table C1.10: Long run effects of fuel taxes on *resource rent*; number of vessels, effort, fuel consumption, CO2 emissions and employment

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Maximum Resource Rent, EUR Million					
DTS 24–40 m	-3.26	0.00	0.00	0.00	0.00
DTS 18–24 m	-0.47	6.79	5.46	6.55	5.77
DTS 12–18 m	0.33	0.21	0.44	0.26	0.38
PAS 10–12 m	-1.59	0.94	0.85	0.97	0.86
TOTAL	-4.98	7.94	6.74	7.78	7.02
Tax revenue (included in RR for scenario 2) 1.44					
Number of vessels					
DTS 24–40 m	13	0	0	0	0
DTS 18–24 m	29	20	16	19	17
DTS 12–18 m	15	1	2	1	2
PAS 10–12 m	55	18	16	19	17
TOTAL	112	39	34	39	36
Effort change					
DTS 24–40 m		-100%	-100%	*-100%*	-100%
DTS 18–24 m		-31%	-44%	*-34%*	-41%
DTS 12–18 m		-93%	-86%	*-92%*	-88%
PAS 10–12 m		-62%	-68%	*-61%*	-65%
TOTAL		-62%	-67%	*-62%*	-65%
Fuel consumption, m^3					
DTS 24–40 m	3,889	0	0	0	0
DTS 18–24 m	4,108	2,819	2,280	2,717	2,426
DTS 12–18 m	756	52	104	62	93
PAS 10–12 m	951	358	306	366	334
TOTAL	9,705	3,229	2,691	3,146	2,853
CO_2 emissions					
DTS 24–40 m	9,723	0	0	0	0
DTS 18–24 m	10,270	7,046	5,701	6,792	6,065
DTS 12–18 m	1,891	129	261	156	232
PAS 10–12 m	2,378	896	766	916	835
TOTAL	24,262	8,071	6,728	7,864	7,132
Employment, full-time equivalents					
DTS 24–40 m	28	0	0	0	0
DTS 18–24 m	79	54	44	52	47
DTS 12–18 m	23	2	3	2	3
PAS 10–12 m	36	23	19	23	21
TOTAL	167	79	67	77	71

Finally, Table C1.11 shows the long-run effects of fuel taxes on revenue per liter, the value of landings and volume, days-at-sea and the volume per day-at-sea. As in the profit scenario, the revenue per liter used increases when the resource rent is maximized, and increases even further when fuel taxes are introduced. The total value of landings decreases when maximizing resource rent, and the volume of landings decreases as well, as does the total number of days-at-sea. Compared to the profit maximizing scenarios, days-at-sea decrease more in the resource rent maximizing scenarios.

Table C1.11: Long run effects of fuel taxes on *resource rent*; revenue per liter, value of landings, landed volume, days-at-sea and volume per day-at-sea

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Revenue per liter used, EUR					
DTS 24–40 m	1.67	0.00	0.00	0.00	0.00
DTS 18–24 m	2.71	3.87	4.12	3.92	4.05
DTS 12–18 m	3.97	6.32	6.63	6.37	6.52
PAS 10–12 m	2.42	4.03	4.22	4.07	4.12
TOTAL	2.36	3.93	4.23	3.99	4.14
Value of landings, million EUR					
DTS 24–40 m	6.50	0.00	0.00	0.00	0.00
DTS 18–24 m	11.14	10.92	9.40	10.65	9.82
DTS 12–18 m	3.00	0.33	0.69	0.40	0.60
PAS 10–12 m	2.30	1.44	1.29	1.49	1.37
TOTAL	22.95	12.69	11.38	12.54	11.80
Volume (1,000 tonnes) of main species					
DTS 24–40 m	17.0	0.0	0.0	0.0	0.0
DTS 18–24 m	26.8	16.5	14.1	16.0	14.7
DTS 12–18 m	10.1	0.6	1.2	0.7	1.1
PAS 10–12 m	3.2	1.3	1.2	1.4	1.3
TOTAL	57.1	18.4	16.5	18.1	17.1
Days-at sea					
DTS 24–40 m	1,256	0	0	0	0
DTS 18–24 m	3,168	2,174	1,759	2,095	1,871
DTS 12–18 m	1,370	94	189	113	168
PAS 10–12 m	5,306	1,999	1,708	2,044	1,863
TOTAL	11,100	4,266	3,656	4,253	3,902
Volume (tonnes of main species) per day at sea					
DTS 24–40 m	13.6	0.0	0.0	0.0	0.0
DTS 18–24 m	8.5	7.6	8.0	7.7	7.9
DTS 12–18 m	7.4	6.2	6.5	6.2	6.4
PAS 10–12 m	0.6	0.7	0.7	0.7	0.7
TOTAL	5.1	4.3	4.5	4.3	4.4

The final rows in Table C1.11 show the volume per day-at-sea. The volume per day-at-sea does not increase in optimum, except for the segment using passive gear. However, the volume per day-at-sea further increases when fuel taxes are introduced, indicating that rising fuel costs will make vessels use their time at sea more efficiently.

Taking a look at the catches from each stock, Table C1.12 shows that catches of all stocks decrease in the profit maximizing scenarios as compared to the current situation. The decrease in catches is most significant for the sprat stock and the herring stock in area 30 (the Bothnian Sea). The cod stocks are less affected. Introducing fuel taxes further reduces catches in all stocks, but the decrease in catches of the different stock are rather similar.

Table C1.12: Landings in tonnes of different species for all segments and different scenarios

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Cod 22–24	1.0	0.8	0.7	0.8	0.8
Cod 25–32	8.3	6.8	6.2	6.8	6.4
Sprat 22–32	9.3	5.5	5.0	5.5	5.1
Herring 25–32	2.4	1.6	1.4	1.6	1.5
Herring 3A+22–24	6.5	4.8	4.4	4.8	4.5
Herring 30	1.1	0.2	0.2	0.2	0.2
TOTAL	28.6	19.8	17.9	19.8	18.3

Gains in our model may be underestimated as effort allocation among stocks is fixed within fleet segments. Each segment is assumed to spend an equal amount of time on each stock. For example, the segment with vessels using passive gear (10–12 m) does not fish the sprat stock. Since the remaining segments (demersal vessels) fish the entire sprat quota, a reduction in effort of the vessels using passive gear will not further increase profits or resource rents in other segments; they cannot increase fishing due to the quota limit for sprat.

C1.4.5 Sensitivity results

In order to check how sensitive our results are to changes in the parameters of the production functions, we run the profit maximization scenario (scenario 1) with three different changes to the parameters. The first analysis (K1) decreases the a-parameters by 25% and keeps the b-parameters at their calibrated values. The second analysis (K2) increases the b-parameter by 25% and the third analysis (K3) decreases the b-parameter by the same amount. The a-parameter is kept at its calibrated value in the second and third analyses.

Table C1.13 shows the effects in scenario 1 (profit maximization) of the sensitivity analysis on profit, the number of vessels, fuel consumption and effort changes. Decreasing the a-parameter (K1) in all stocks for all segments results in a lower total profit, which is expected, since parameter a is an indication of the volume of landings. All segments, except the small trawler segment (DTS 12–18 m), get lower profits. However, the ranking of segments is unchanged and the exit of the large trawlers (DTS 24–40 m) remains. Changing the b-parameter also preserves the ranking of segments and results in the larger trawlers leaving the fishery. Profit is larger in sensitivity analysis K3 than in sensitivity analysis K2.

Table C1.13: Sensitivity analysis: Effects on profit, number of vessels, fuel consumption and effort

	Originallycalibrated values of a and b	K1: parameter a decreasing by 25%	K2: parameter b increasing by 25%	K3: parameter b decreasing by 25%
Profit, EUR Million				
DTS 24–40 m	0.0	0.0	0.0	0.0
DTS 18–24 m	8.0	3.7	6.2	9.5
DTS 12–18 m	0.2	1.3	0.5	0.3
PAS 10–12 m	2.4	2.2	2.6	3.1
TOTAL	10.6	7.2	9.3	12.9
Number of vessels				
DTS 24–40 m	0	0	0	0
DTS 18–24 m	22	13	16	26
DTS 12–18 m	1	8	2	1
PAS 10–12 m	28	28	29	36
TOTAL	51	48	48	63
Fuel consumption, m^3				
DTS 24–40 m	0	0	0	0
DTS 18–24 m	3,083	1,787	2,335	3,704
DTS 12–18 m	54	385	124	65
PAS 10–12 m	543	536	560	700
TOTAL	3,681	2,708	3,020	4,469
Change in effort				
DTS 24–40 m	-100%	-100%	-100%	-100%
DTS 18–24 m	-25%	-56%	-43%	-10%
DTS 12–18 m	-93%	-49%	-84%	-91%
PAS 10–12 m	-43%	-44%	-41%	-26%
TOTAL	-50%	-54%	-54%	-38%

Looking at the number of vessels, a similar pattern appears again. Decreasing the a-parameter results in more small trawlers (12–18 m) staying in the fishery and more medium trawlers (18–24 m) leaving. This is also what happens when increasing the b-parameter although to a smaller extent. Decreasing the b-parameter results in more vessels staying in all segments.

Decreasing the a-parameter results in less fuel consumption and less effort in the fishery. This also happens when increasing the b-parameter. Again, the smaller trawler segment (12–18 m) is less affected in analyses K1 and K2 than in the original analysis, fuel consumption increases more and effort is decreasing to a smaller extent. In summary, the effect on the smaller trawler segment might not be as large as in the original analysis, but the ranking of segments is preserved in the sensitivity analysis.

C1.5 Conclusions

Maximizing the profit or resource rent in the fishery increases the economic performance and reduces the fleet size compared to the current fleet. Introducing fuel taxes in the optimized fishery will further reduce the fleet, but also reduce economic performance. This is expected since fuel taxes imply a cost increase. However, the effects of taxes are small compared to the effects of optimizing the fishery. The optimized fishery is robust to changes in fuel costs. We find some evidence that fuel-efficient fishing techniques gain an advantage when fuel costs are high, but the effects are small. Optimizing the fishery will increase fuel efficiency (revenue/liter fuel), and higher fuel cost will contribute to further increased efficiency.

References

Stern, N. (2006), Review on the Economics of Climate Change, Cambridge University Press.

Swedish Tax Authority, excel sheet "historiska skattesatser" at http://www.skatteverket.se/foretagorganisationer/skatter/punktskatter/energiskatter.4.18e1b10334ebe8bc8000843.html

ICES Advice 2012, Book 1 – Introduction, overviews and special requests, ICES 2012.

C2. Denmark

Max Nielsen, University of Copenhagen, Frank Jensen, University of Copenhagen

C2.1 Introduction

Fuel is important for many industries. However, fuel generates externalities such as emissions and, therefore, regulation is necessary. Taxes and transferable quotas are among the fuel policies that society can choose. The policy instrument actually used is taxes, but an EU quota system is also present. Fishermen are exempted from taxes and quotas, which is the same as giving fishermen a subsidy. A question that arises is whether such a subsidy is optimal. After all, fuel use generates externalities and, therefore, regulation is necessary.

In this note we discuss the effects of including fisheries in the national tax policy and EU quota system. We consider long-run effects by studying the effects after all adjustments have taken place. Effects on resource rent, profit, number of vessels, CO_2 consumption and fuel consumption are considered. One result is that, compared to the existing situation, the effect of optimal management is very large. However, we underestimate the effect of various fuel policies. We conduct a bio-economic analysis with three fleet segments and study adjustments within fleet segments and, to some extent, between fleet segments. The fleet segments fish both common and separate stocks. If all fish the same stocks, only the most efficient will survive. In our case some vessels survive because they fish separate stocks. Therefore, we underestimate the adjustment between fleet segments of various fuel policies.

C2.2 Scenarios

In this paper we consider four alternatives concerning the cost function:

- The baseline case without fuel and energy taxes.
- The case where fishermen pay the existent CO_2 and energy taxes in the country (Birk-Mortensen (2009)).

- The case where the existent CO_2 permit price of EUR/1,000 l. 34.01 for coal, oil, natural gas and electricity is paid in the EU (Stern (2006)).
- The case where fishermen pay the long-run equilibrium permit price of EUR/1,000 l. 159.02 in the EU according to Stern (2006).

The four alternatives correspond to different assumptions about fuel costs. In the first case no fuel and energy taxes are paid. This corresponds to the existing tax structure in the Nordic countries. The second case arises when the existing fuel and energy tax in a country is paid. Here the fishing sector pays exactly the same taxes as other industries. The existing CO_2 permit price in the EU is paid in the third case. This is the case where the national fishing sector is included in the EU permit market. In the last case the long-run equilibrium (year 2100) permit price is paid based on the forecasted price in Stern (2006). Here the fishing industry is also included in the EU permit market and the long-run value of permits is the relevant cost to include.

These four alternatives are evaluated using both profit and resource rent. The resource rent and profit are evaluated in three steps. First, the revenue is identified using biological information. Second, costs are arrived at. Last, the maximum resource rent and profit are calculated. In scenarios 2, 3 and 4 the total resource rent can be maximized, given that vessels can freely exchange quotas with each other. Effort adjustments are identified, both totally and for each fleet segment. In addition, CO_2 consumption and fuel consumption are identified for each fleet segment.

Finally, we turn to a description of the results.

C2.3 Data

C2.3.1 Danish CO2 regulation and EU quota system

The Danish fuel policy consists of two parts:

- Energy taxes.
- An EU quota system.

With respect to energy taxes, two types of fees exist. First, there are energy taxes on oil, coal, natural gas and electricity. Second there are CO_2 taxes on products that are included in the energy tax. The energy tax corresponds to a fee that is 48.6 kr, pr. GJ. The CO_2 tax is determined on the basis of a tax that is 150 kr. pr. tonne, which corresponds to the expected quota price. Vessels are exempted from payment of all energy and CO_2 taxes. This is the same as giving the fishery a subsidy for fuel use.

With respect to the EU quota system this was introduced in 2002 on CO_2 emissions. The first period, between 2005 and 2007, was an introduction period. The current period is between 2008 and 2012. In Denmark the 374 production units, comprising mostly the energy sector and large energy consuming industries, which are included in the quota system, emit half of the CO_2 in Denmark. Households, agriculture, transportation and fisheries are not included in the EU quota system. Thus, as with energy and CO_2 taxes, vessels are not included in the EU quota system. Again, this is the same as giving fisheries a subsidy for fuel consumption. In this project we highlight what happens to fisheries if this sector is included in the national tax system and EU quota system. Thus, we answer the question of what happens to fisheries if the fuel subsidies are removed.

C2.3.2 Economic data

Table C2.1 summarizes the current energy and CO_2 taxes in Denmark. In addition, current EU CO_2 prices and predicted CO_2 quota prices in the EU according to Stern (2006) are presented.

Table C2.1: Danish CO2 and energy taxes, current EU quota price on CO2 and optimal CO2 quota price forecasted in year 2100, EUR/tonne CO2 and EUR/1,000 liter fuel

	EUR/tonnes CO_2	EUR/1,000 liter fuel
Danish energy tax 2009	125.25	*313.14*
Danish CO_2 tax 2009	21.34	*53.35*
EU CO_2 quota price 2009	*13.6*	34.01
Optimal CO_2 quota price year 2100 Stern (2006)	*63.60*	159.02

Note: The *italic* numbers are known. Recalculation between the two units are made with an average CO2 -efficiency of engines in Danish fishing vessels of 2.5 kilo CO2 per liter fuel.
Source: Stern (2006) and the Danish Tax Ministry (2009).

The total Danish energy tax and CO_2 tax in 2009 was EUR/1,000 liter fuel 366.49. Of this,EUR/1,000 liter fuel 313.14 is energy tax and EUR/1,000 liter fuel 53.35 is CO_2 tax. The tax of EUR/1,000 liter fuel is arrived at by multiplying the tax in EUR/tonnes by 2.5 where 2.5 is the energy efficiency. The EU CO_2 quota price in 2009 was EUR/liter 34.01, while the predicted quota price in 2100 is EUR/1,000 liter 159.02. Note that the EU CO_2 quota price is considerably below the existing Danish taxes. Therefore, a lower resource rent and profit must be predicted when using Danish taxes and when using EU quota prices.

In Table C2.2 physical and economic data for selected fleet segments (net/hook < 12 m, net/hook 12–18 m and trawl < 18 m) is sketched.

Table C2.2: Physical and economic data for Danish net and trawl fleets below 18 m, 2010

	Net/hook <12 m	Net/hook 12–18 m	Trawl <18 m	Total
Physical data				
Full-time employment	103	61	105	269
Number of vessels	130	42	147	319
Physical assets (EUR Million)	10.6	17.3	46.7	74,6
No. of days at sea per vessel	99	143	141	124
Fuel consumption (1,000 liter)	12,270	14,890	102,760	129,920
Share of national landing value (%)	2,7%	3,5%	10,7%	16,9%
Main stocks[1]	Cod (3AN+4) Cod (3BC) Cod (3D) Sole (3ABC)	Cod (3AN+4) Sole (4) Plaice (4)	Nephrops (3A) Cod (3D) Sand eel (3A+4) Sprat (3BC) Cod (3AN+4)	.
Share of main stocks of value (%)	54%	62%	63%	61%
Account data (EUR Million)				
Turnover	23	24	96	140
Fuel costs	0.7	0.9	5.5	7.1
Salary	6.2	4.9	16.2	27.3
Other operating costs	4.6	4.2	13.3	22.1
Capital costs	0.6	1.2	3.5	5.3
Depreciation	1.3	1.3	4.1	6.7
Salary per FTE (EUR/year)	60,194	80,328	79,024	74,185
Opportunity cost				
Salary (EUR/year)	40,000	40,000	40,000	40,000
Capital (%)	6	6	6	6

Note: Numbers and letter refer to the stock in the specified ICES area in the Northeast Atlantic Ocean. Sources: Landings Statistics from the Danish Directorate of Fisheries and Account Statistics for fisheries from Statistics Denmark.

Concerning full-time employment, trawl < 18 m has the largest number of employees (205), while net/hook 12–18 m has the lowest. However, the number of vessels is also largest for trawl < 18 m (147) compared to net/hook 12–18 m (42). Net/hook < 12 m has only slightly fewer vessels (130) than trawl < 18 m, but the number of employees is much lower (103). With respect to physical assets trawl < 18 m also has the largest amount (mil. EUR 46.7). The next highest amount of physical assets is in the fleet segment net/hook 12–18 m (mil. EUR 17.3), while net/hook < 12 m (mil EUR 10.6) has the lowest.

With regard to number of days at sea per vessel, this performance measure is approximately equal for net/hook 12–18 m (141) and trawl < 18 m (143), while net/hook < 18 m has a lower number (99). With respect to fuel consumption trawl < 18 m has a much larger consumption (10,276 million l.) than net/hook 12–18 m (1,489 mil l.) and net/hook < 12 m (1,227 million l.). Thus, a change in the fuel policy as considered in this project will influence trawl < 18 m more than net/hook < 12 m and net/hook 12–18 m. Concerning the size of the fishery compared to the national fishery, the share of national landings value is also reported in Table 2. It is seen that trawl < 18 m lands 10.7% of national landings while net/hook 12–18 m only lands 3.6% and net/hook < 12 m lands 2.7%. Thus, trawl < 18 m is the largest fleet segment.

The main stocks are also reported in table C2.2. Trawl < 18 m has nephrops in Skagerrak/Kattegat, cod in the East Baltic Sea, Sand eel in the North Sea/Skagerrak, sprat in the West Baltic Sea and cod in the North Sea/Skagerrak as main stocks, while net/hook 12–18 m fishes cod in the North Sea/Skagerrak, sole in the North Sea and plaice in the North Sea. Finally, net/hook < 12 m fishes cod in the North Sea/Skagerrak, cod in the West Baltic Sea, cod in the East Baltic Sea and sole in Skagerrak/Kattegat/West Baltic Sea as main stocks. The share of main stock value varies between 63% (trawl < 18 m) and 54% (net/hook < 12 m).

Turning our attention to account data (mil. EUR), the turnover is largest for trawl < 18 m and lowest for net/hook < 12 m. The turnover for net/hook 12–18 m is close to the turnover for net/hook < 12 m. Fuel costs are also largest for trawl < 18 m (5.5) and approximately equal for net/hook < 12 m (0.7) and net/hook 12–18 m (0.9). Thus, a change in the prices of fuel will mostly influence trawl < 18 m.

That trawl < 18 m is the largest of the three fleet segments is also seen from the salary. The salary is mil. EUR 16.2 for trawl < 18 m, and much lower for net/hook < 12 m (6.2) and net/hook 12–18 m. Other operating costs are also largest for trawl < 18 m (13.3) and approximately equal for net/hook < 12 m (4.6) and net/hook 12–18 m (4.2). The same conclusion holds for capital costs and depreciation, but, with total values of 5.3 (capital costs) and 6.7 (depreciation), these two performance measures are low compared to other costs. For calculation of the resource rent, we need a measure for opportunity costs. From Table C2.1 we see that a salary of 40,000 (EUR pr year) and an interest rate of 6% measure the alternative use of labor and capital.

C2.3.3 Biological data

Information about fish stocks can be found in Table C2.3. Cod in the North Sea/Skagerrak, cod in the West Baltic Sea and sole in the North Sea all have a fishing mortality above target. However, cod in the North Sea/Skagerrak have a spawning stock that is lower than the maximum biomass, while cod in the West Baltic Sea and sole in the North Sea have a biomass that is approximately equal to the maximum biomass.

Table C2.3: Actual spawning stock biomass, spawning stock which offers the largest renewable catches and fishing mortality levels, tonnes

	Spawning stock biomass		Fishing mortality compared to MSY-level
	Actual 2010	**Maximum**	
Cod:			
North Sea/Skagerrak (3AN+4)	52,700	150,000	Above target
West Baltic Sea (3BC)	25,600	23,000	Above target
East Baltic Sea (3D)[1]	133,200	290,000	Appropriate
Sole:			
North Sea (4)	35,200	35,000	Above target
Skagerrak/Kattegat/West Baltic Sea (3ABC)	1,800	2,000	Below target
Plaice North Sea (4)	460,700	230,000	Appropriate
Nephrops Skagerrak/Kattegat (3A)[2]	80,000	64,800	Appropriate
Fish for reduction:			
Sand eel North Sea/Skagerrak (3A+4)[3]	331,800	215,000	Not defined
Sprat West Baltic Sea (3BC)[4]	891,000	910,000	At risk

Note:

1 The spawning stock biomass corresponding to the precautionary approach for the East Baltic cod stock remains undefined and the maximum on 290,000 tonnes is the forecast for 2013 following the management plan until then.

2 The spawning stock biomasses remain undefined. Therefore, the values provided are based on the known harvest ration of 6.4% in 2010 and 7.9% in MSY.

3 Sand eel includes only estimates for the Dogger Bank area.

4 The maximum spawning stock biomass for sprat in the West Baltic Sea remains unknown and the number included is the smallest possible spawning stock biomass consistent with the precautionary approach, given different catch levels in 2010.

Source: ICES (2010).

For cod in the East Baltic Sea, plaice in the North Sea and nephrops in Skagerrak/Kattegat the fishing mortality is considered appropriate. The maximum stock for cod in the East Baltic Sea is above the maximum stock, while the maximum stock is below the actual stock for plaice in the North Sea and nephrops in Skagerrak /Kattegat. Sole in Skagerrak/Kattegat/West Baltic Sea have an actual stock that is slightly below the maximum value, but the fishing mortality is considered to be below target. For sprat in the West Baltic Sea the actual stock is approximately equal to the maximum stock, but the fishing mortality is considered to be at risk. For sand eel in the North Sea/Skagerrak the fishing mortality is not defined, but the actual stock is above the maximum stock. Next, we turn to a description of the model we use for analysing the effects of various fuel policies.

C2.4 Results

We start by discussing the calibrated parameter values in the production function. These parameters can be found in Table C2.4.

Table C2.4: Calibrated Parameter Values of the Production Function

	Net/hook <12 m	Net/hook 12–18 m	Trawl <18 m
Parameter a:			
Cod North Sea/Skagerrak	739	3,642	436
Cod West Baltic Sea	154	.	.
Cod East Baltic Sea	211	.	650
Sole North Sea	.	83	.
Sole Skagerrak/Kattegat/West Baltic Sea	24	.	.
Plaice North Sea	.	335	.
Nephrops Skagerrak/Kattegat	.	.	207
Sand eel North Sea/Skagerrak	.	.	1,576
Sprat West Baltic Sea	.	.	1,208
Parameter b:			
Cod North Sea/Skagerrak	0.2100	0.4600	0.1400
Cod West Baltic Sea	0.0700	.	.
Cod East Baltic Sea	0.067	.	0.0420
Sole North Sea	.	0.1700	.
Sole Skagerrak/Kattegat/West Baltic Sea	0.0890	.	.
Plaice North Sea	.	0.0830	.
Nephrops Skagerrak/Kattegat	.	.	0.0390
Sand eel North Sea/Skagerrak	.	.	0.0310
Sprat West Baltic Sea	.	.	0.0500

For the production function the following expression is used:

$$Q = aEe^{-bE}$$

where:

Q is landings
E is effort
e is the natural number.

Using a procedure from Nielsen *et al.* (2011), the parameters a and b are calibrated. The results of this calibration are shown in Table C2.4. As seen from this table, the calibration is done for each fleet segment and each stock. The largest value of a is reached by net/hook 12–18 m fishing cod in the North Sea and Skagerrak. The vessels in this group also have the highest value of b. A large value of b is also obtained for net/hook < 12 m fishing cod in the North Sea. For this fleet segment a medium value of a is obtained. A large value of a is obtained for trawl < 18 m fishing sand eel in the North Sea and Skagerrak and trawls < 18 m fishing sprat I the West Baltic Sea. However, these fleet segments have a low value of a. Concerning trawl < 18 m fishing cod in the North Sea, a large value of b and a medium value of a are obtained. Net/hook fishing cod in the west Baltic Sea and cod in the east Baltic Sea, Net/hook 12–18 m fishing plaice in the North Sea, Trawls < 18 m fishing cod in East Baltic Sea and neprophs in Skagerrak and Kattegat all result in medium values for a and b. Net/hook exploiting the stock of sole in the North Sea and net/hook 12–18 m fishing sole in the North Sea all have a low value of a.

We now turn to the scenarios:

0. Baseline – current profit and resource rent both with and without taxes(=2010).
1. Maximization of profit and resource rent without energy and CO_2 taxes.
2. Maximization of profit and resource rent with current national energy and CO_2 tax structure imposed on fisheries.
3. Maximization of profit and resource rent with current CO_2 quota prices imposed on fisheries.
4. Maximization of profit and resource rent with predicted CO_2 quota prices imposed on fisheries in 2100.

With respect to profit, all three vessel groups yield a negative profit in the short-run both with and without taxes. An implication of the negative profit is that none of the vessels should operate in the short run. Alternatively it can be shown that Trawl < 18 m is the only fleet segment that should operate in scenarios 1 and 3, while net/hook 12–18 m is the only fleet segment that should fish in scenarios 2 and 4. Concerning resource rent, net/hook < 12 m operates with a negative value with and without taxes. Thus, it is not optimal to have this fleet segment operating in the short run. Trawl < 118 m yields the highest rent in the short run while net/hook 12–18 m yields a smaller but positive resource rent.

Table C2.5: Long run effects of fuel taxes on *profit* with perfect flexible adjustment to MEY, EUR Million, number of vessels, percentage effort change, 1,000 l fuel and tonnes CO_2

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Maximum profit					
Net/hook <12 m	-21(-23)	34	34	34	34
Net/hook 12–18 m	-3(-4)	69	68	69	69
Trawl <18 m	*0(-1)*	*95*	*87*	*94*	*91*
Total	-24(-28)	198	189	197	195
Number of vessels					
Net/hook <12 m	130	40	39	40	39
Net/hook 12–18 m	42	14	13	14	14
Trawl <18 m	*147*	*59*	*54*	*59*	*57*
Total	319	113	107	113	110
Effort change					
Net/hook <12 m	.	-69	-70	-69	-70
Net/hook 12–18 m	.	-68	-68	-68	-68
Trawl <18 m	.	*-60*	*-63*	*-60*	*-61*
Total	.	-64	-66	-64	-65
Fuel consumption					
Net/hook <12 m	12,270	3,780	3,690	3,800	3,650
Net/hook 12–18 m	14,890	4,840	4,760	4,840	4,790
Trawl <18 m	*102,760*	*41,380*	*38,040*	*41,270*	*40,140*
Total	129,920	49,990	46,500	49,910	48,590
$C0_2$ consumption					
Net/hook < 12 m	30,680	9,440	9,230	9,490	9,140
Net/hook 12–18 m	37,230	12,090	11,910	12,100	11,970
Trawl < 18 m	*256,900*	*103,450*	*95,110*	*10,3,190*	*100,350*
Total	324,810	124,980	116,240	124,470	121,460

* taxes in parenthesis.

Table C2.6. Long run effects of fuel taxes on *resource rent* with perfect flexible adjustment to MEY, EUR Million, number of vessels, percentage effort change, 1,000 l fuel and tonnes CO_2.

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Maximum resource rent					
Net/hook <12 m	-6(-8)	38	37	38	38
Net/hook 12–18 m	17(15)	75	74	75	74
Trawl <18 m	64(61)	122	111	121	117
Tax revenue	.	.	2	.	.
Total	75(68)	234	224	234	229
Number of vessels					
Net/hook <12 m	130	44	42	44	44
Net/hook 12–18 m	42	15	14	15	15
Trawl <18 m	147	72	65	72	70
Total	319	131	122	131	128
Effort change					
Net/hook <12 m	.	-66	-68	-66	-66
Net/hook 12–18 m	.	-65	-66	-65	-65
Trawl <18 m	.	-51	-56	-51	-53
Total	.	-58	-61	-58	-59
Fuel consumption					
Net/hook <12 m	12,270	4,130	3,990	4,160	4,120
Net/hook 12–18 m	14,890	5,200	5,100	5,200	5,170
Trawl <18 m	102,760	50,590	45,660	50,450	48,760
Total	129,920	59,920	54,740	59,850	58,050
CO_2 emissions					
Net/hook < 12 m	30,680	10,330	9,960	10,390	10,290
Net/hook 12–18 m	37,230	13,000	12,740	13,010	12,930
Trawl < 18 m	256,900	126,480	114,140	126,120	129,100
Total	324,810	149,800	136,850	149,620	145,120

* taxes in parenthesis.

Concerning long-run effects, Table C2.5 and Table C2.6 report the results for profit, resource rent and fleet size with perfectly flexible adjustments to optimum. In total, 319 vessels exploit the resource in the current situation without taxes. Most of the vessels are net/hook < 12 m and trawl < 18 m. With respect to the four scenarios, there is very little variation in the profit, number of vessels and resource rent. The profit varies between EUR 189m and EUR 198m. The largest profit is obtained for trawl < 18 m while the smallest profit is for net/hook < 12 m The variation in profit is mainly due to variation in the yield for trawlers < 18 m. Regarding the number of vessels under profit maximization, the majority of the vessels are trawl < 18 m. Irrespective of the fact that net/hook 12–18 m earn a higher profit than net/hook < 12 m, there are more vessels in the second category (net/hook < 12 m) than in the first category (net/hook 12–18 m). Concerning resource rent, this rent is larger than the profit. As for profit maximization, variations in the resource rent are almost within the group trawl < 18 m. There are also more vessels with resource rent maximization than with profit maximization. The smallest number of vessels and resource rent are obtained with tax exemption withdrawn. However, if we include tax revenue in the resource rent, this yield is almost identical for all four scenarios.

Table C2.5 and C2.Table 6 also report the change in effort compared to the current situation without taxes and with taxes for all four scenarios (profit and resource rent with taxes is in parentheses). In Table C2.5 and Table C2.6 the % change in effort is almost identical for both profit and resource rent. However, there is some reallocation for both measures between groups. Trawlers < 18 m are the category with the smallest reduction in effort, while net/hook < 12 m and net/hook 12–18 m have almost identical reductions in effort. For resource rent maximization compared with profit maximization, the reduction is largest with profit as the objective. This can be explained by the fact that there are fewer vessels with profit maximization. Table C2.5 also reports the results for fuel consumption and CO_2 consumption. With respect to fuel consumption, this is largest in scenario 1 followed by scenarios 3, 4 and 2. These results are as expected. However, the variation in fuel consumption is almost entirely due to variations for trawl < under 18. M. CO_2 consumption follows exactly the same pattern. This is due to the fact that CO_2 consumption is reached by multiplying fuel consumption with the same constant.

Note that the real gain in rents may be underestimated. This arises because of an assumed fixed effort allocation between stocks within each fleet segment. If a fleet segment fishes at least one stock the other fleet segments do not fish on, the separate stock will constitute the restriction. In this way we do not get full fleet adjustment. Hence the gain in rents is underestimated.

From Table C2.5 and Table C2.6 we also see that the effect of moving from the current situation with and without taxes to optimal management (scenarios 1–4) is very large, but that the effect of the different fuel policies is very small. However, as mentioned in the introduction, we underestimate the effect of the different fuel policies. In the fishery we consider that the fleet segments fish both common and separate stocks, but if they fish common stocks, only the most efficient will survive. In our case some vessels survive because they fish separate stocks and, therefore, we underestimate the economic effects of various fuel policies.

Table C2.7 and Table C2.8 report the number of full-time employees, landings and value of landings in the current situation with and without taxes and the four scenarios.

Table C2.7: Long run effects of fuel taxes on *profit* with perfect flexible adjustment to MEY, number, 1,000 tonnes and EUR Million

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Employees					
Net/hook <12 m	103	36	34	36	34
Net/hook 12–18 m	61	21	21	21	21
Trawl <18 m	205	64	62	64	63
Total	369	121	117	121	118
Landings					
Net/hook <12 m	60	17	17	17	17
Net/hook 12–18 m	80	29	29	29	29
Trawl <18 m	520	197	201	200	199
Total	660	243	247	244	245
Value of landings					
Net/hook <12 m	10	56	56	56	56
Net/hook 12–18 m	19	91	92	91	92
Trawl <18 m	66	110	107	110	108
Total	95	257	256	257	255

Table C2.8. Long run effects of fuel taxes on *resource rent* with perfect flexible adjustment to MEY, number, 1,000 tonnes and EUR Million

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Employees					
Net/hook <12 m		38	36	38	38
Net/hook 12–18 m		22	22	22	22
Trawl <18 m		69	67	69	68
Total		129	125	129	127
Landings					
Net/hook < 12 m	60	20	20	20	20
Net/hook 12–18 m	80	31	31	31	31
Trawl < 18 m	520	207	205	207	206
Total	660	258	256	258	257
Value of landings					
Net/hook <12 m	10	68	68	68	69
Net/hook 12–18 m	19	86	83	85	85
Trawl <18 m	66	141	126	141	137
Tax revenue	95	.	2	.	.
Total		295	279	295	290

From Table C2.7 and Table C2.8 we see that there is very little variation among the four scenarios if we consider full-time employees. However, there is a large difference in the number of employees if we compare the current situation with the four scenarios. This conclusion holds for both resource rent and profit. The same pattern is also found for landings and value of landings for both profit and resource rent. The differences among the four scenarios are very small, while the difference between the current situation and the scenarios is very large.

Table C2.9 shows the effect in scenario 1 of varying a and b. This sensitivity analysis is performed with a decrease in a of 25% and a change in b of +/- 25%. We report values for changes in profit in Table C2.7.

Table C2.9: Sensitivity analysis, profit and fuel consumption with decrease in a of 25% and increase and decrease in b of 25%. Scenario 1, EUR Million and m^3

	Originally calibrated values of a and b	Parameter a decreasing by 25%	Parameter b increasing by 25%	Parameter b decreasing by 25%
Maximum profit				
Net/hook <12 m	34	22	30	41
Net/hook 12–18 m	69	67	66	75
Trawl <18 m	95	90	92	102
Total	198	179	188	218
Fuel consumption				
Net/hook <12 m	3,780	2,445	3,335	4,570
Net/hook 12–18 m	4,840	4,600	4,630	5,261
Trawl <18 m	41,380	39,203	40,073	44,430
Total	49,990	46,248	48,038	54,261

Concerning profit, this evaluation criterion falls with a decrease in a. This conclusion holds for all fleet segments. The change in profit is largest for net/hook < 12 m. Profit also falls with an increase in b for all fleet segments, and changes in absolute values are almost identical between fleet segments. For a decrease in b the profit increases. Table C2.9 also reports the change in fuel consumption. This change follows the change in profit. A decrease in a and increase in b results in a lower fuel consumption, while the fuel consumption increase with a decrease in b.

C2.5 Conclusions

In this note we consider the effect of various fuel policies on the performance of fisheries. We consider five scenarios:

0. The present situation with exemption of fuel and energy taxes and with fuel and energy taxes.
1. Optimization in the present situation.
2. National tax policy imposed on fisheries.
3. Current EU CO2 quota prices used in fisheries.
4. Long-run EU CO2 quota price according to Stern (2006).

The difference between the two present situations and four other scenarios is large. Therefore, there is a considerable gain in moving to optimal management. However, the differences among the last four scenarios are small. This conclusion holds irrespective if the effect is measured in profit, resource rent, number of vessels, effort, CO_2 consumption, number of employees, value of landings or fuel consumption. Thus, there is very little to be gained when choosing between various fuel policies. The policy implication of this is that the most efficient policy is not a fuel policy, but simply a movement to economic optimal management such as individual transferable quotas. However, we may underestimate the gain of choosing between fuel policies. We analyse three separate fleet segments and study both within and between fleet segment adjustments. The fleet segments harvest both common and separate stocks. In the situation where all fish the same stocks, only the most efficient survive. However, when fishing separate stocks, as in our case, some will survive because of this. Therefore, we underestimate effort reallocation and the gain of different fuel policies.

References

Birk- Mortensen (2009), EU CO2 kvotemarkedet – facts and implications. Information, 23/1-2009.

International Council for Exploration of the Sea/ICES (2010), Report from the Advisory Committee of Fisheries Management, available at http://www.ices.dk/indexfla.asp

Stern, N. (2006), Review on the Economics of Climate Change, Cambridge University Press.

C3. Norway

Ola Flaaten, University of Tromsø; Nguyen Ngoc Duy, University of Tromsø; Øystein Hermansen, Nofima; John R. Isaksen, Nofima

C3.1 Introduction

Norway has ambitious objectives for its environmental and resource policy, in addition to economic growth. In short this may be characterized as sustainable growth and development, officially pursued in the policy design in all sectors of the economy. These objectives are backed by strong analytical focus within ministries, governmental agencies and research and higher teaching institutions. Objectives to promote sustainable development include, within areas of climate change, biodiversity, marine environment, resource and waste management. Mitigation of greenhouse gas (GHG) emissions is to meet Norway's international obligations as well as to reduce local pollution, in particular in densely populated areas.

Legal (regulations) and economic policy instruments are used to achieve the environmental and resource objectives. Cost-effectiveness is one of the criteria emphasized, at least in principle, whenever new policy instruments are designed and implemented. These instruments include several taxes, often called green taxes, already implemented gradually soon after the Second World War. The CO_2 tax was introduced in 1991 and the base tax on mineral oil in 2000. In principle, such taxes should apply across industries and geographical areas, but there is no rule without exceptions.

C3.2 Background

In the Norwegian part of this work we will concentrate on two important vessel groups/fisheries within Norwegian fisheries. Both groups are engaged in the demersal fisheries (for mainly cod, haddock and saithe) and are important raw material vendors for the fish processing industry in the North of Norway. On the one hand, we include smaller coastal vessels (11–15 m overall length), the most numerous vessel group within Norwegian fisheries, utilizing passive and active gear (gillnet, hand-line, long-line and Danish seine) along the coast. The second group is the cod trawlers, consisting of about 40 large vessels fishing with trawl. Needless to say, the coastal vessels are considerably more fuel efficient than the cod trawlers. Together, these vessel groups catch about half of the annual Norwegian cod quota.

C3.2.1 Regulation system

Norwegian fleet capacity regulations date back to the prohibition of trawlers in 1908, and a license system for trawlers was implemented in 1932. TACs restrict the total uptake of most commercial species, minimum fish size and discard bans are set to avoid fishing of illegal fish, and all catches are counted against the particular species quota.

In short, Norwegian vessels participating in most commercial fisheries are either granted a license (mainly for the larger off shore vessels like the cod trawlers) for unlimited time, or annual fishing permits (the coastal fleets) renewable each year. Both give the vessel the right to fish a defined share of the annual quota of the species. The Norwegian regulation system is characterized by so-called quasi-ITQs for both vessel groups that we address here (coastal vessels; 11–15 m overall length, and cod trawlers). "Quasi" since the right to fish is exclusively linked to the ownership of the vessel that in fact holds the license (or the annual permit), and cannot be transferred unconditionally.[7] By law, majority owners of fishing vessels have to be registered as active fishermen, with some exemptions.

Fishing effort is controlled by input and output regulations. The licenses and permits described above belong to the first class of measures (input) and open access fisheries (for registered fishermen with fishing vessels) exist only to a limited extent. The output regulations refer to the division of TAC shares of all regulated stocks among vessels groups, and participating vessels (holding licenses or permits). There are also rules regarding periodization of harvest/catch, maximum legal bycatch, start and stop dates, etc., for fisheries both within and outside the Norwegian EEZ (the latter as parts of bi-/unilateral agreements with other states). The TAC share for vessel groups is mainly divided among participants as Individual Vessel quotas, but in some instances, when the groups of vessels are heterogeneous (like in the coastal fishery for cod), maximum quotas are allocated among vessels; summed up the quotas are greater than the group quota (so-called over regulation). Then, fishing ceases when group quotas are taken, irrespective of whether allotted individual vessel quotas are taken. In recent years the degree of over regulation has

---

[7] Williams and Hammer (2000: 196) denote the Norwegian arrangement as "*...more a system of Individually Transferable Access instead of ITQs*". Much of what is mentioned here is based on their article.

been reduced in the coastal fisheries as well, and individual vessel quotas are the rule – not the exception. As an instrument to utilize national TACs, re-allocation of group quotas and favorable by-catch quotas among vessel groups is used. In addition, authorities try to achieve a stable and high-quality supply to the processing industry through their regulation, since one objective is to maximize value creation in the whole fisheries sector. This is partially attended to by the delivery obligation in about half of the cod trawler licenses.

C3.2.2 Norwegian CO_2 regulation[8]

Norway has had long experience of environmental taxation. Taxation had an environmental impact long before taxes were established as an instrument in environmental policy. Norway had already introduced a petrol tax in 1931. The first tax with an explicit environmental purpose was the sulphur tax on mineral oil in 1971. A wide-spread use of environmental taxes has been seen since the late 1980s and early 1990s. Taxes on lubricant oil and the like were introduced in 1988, and CO_2 tax was imposed on petrol, auto diesel oil, mineral oil and the offshore petroleum sector in 1991, but not on fisheries and some other industries. Since the early 1990s tax instruments have played an important role in providing incentives for cleaner production and consumption patterns, even though regulation has remained the main policy instrument to abate environmental damage.

Some taxes have been increased substantially over the years, but at the same time exemptions and reduced rates for some industries have been introduced. In Norway, 4.2% of central government tax revenue is due to environmental and energy taxes, equivalent to 1.6% of GDP (estimates based on the 2006 budget). The level of green taxation is one of the highest in the OECD area. Environmental taxes refer to taxes with an explicit environmental purpose (e.g. CO_2 and sulphur taxes). By the end of the 1980s the Government's opinion on the use of environmental taxation had become markedly more positive. Several Governments have envisaged that increased revenue from environmental taxation could be used for reducing other taxes. In the early 1990s a Government appointed Commission revealed that 40% of CO_2 emissions and 60% of SO_2 emissions were exempt from taxation. It also criticized the weak correspondence between the CO_2 tax rate and the carbon content of different fuels.

---

[8] Based on material from The Ministry of Finance, Norwegian Customs and the OECD. The discussion is limited to the taxes of most importance for fisheries.

The CO_2 tax should in principle be applied at the same rate for emissions from all fossil fuels and uses. However, costs of restructuring in industries and adaptation in local communities should be considered when introducing and increasing CO_2 taxation.

A committee on "Instruments in Environmental Policy" in 1995 advised the environmental authorities to assess possible alternatives to the concession system which had developed in parallel to taxes. A mix of environmental taxes, tradable emission quotas, legislation (general rules), voluntary agreements, and environmental quality standards were recommended. In 1996 another committee recommended changes to achieve both a better environment and high employment. Cost efficiency should be a fundamental principle in the formulation of climate policy. In the case of CO_2 emissions, this means that all products/uses of fossil fuels in principle should bear the same tax per unit emission, not just in Norway, but in all countries. The Commission admitted that it will be difficult in the short run to ensure an optimal policy structure across countries. Norwegian CO_2 taxes should therefore be considered as an element of Norway's role as an instigator in the area of climate policy. This complicates the task of formulating a cost efficient structure of CO_2 taxes in Norway. The level of taxation must therefore be determined on a more pragmatic basis, against the costs for Norway of being the pioneer in this area. The majority of the Commission proposed a low CO_2 tax rate for fuels and sectors that were exempted, while a minority opposed any expansion of the CO_2 tax.

In 1998 the parliament, Stortinget, approved a general expansion of the SO_2 tax. The CO_2 tax was extended to air transport (later withdrawn due to international air transport agreements), domestic sea transport of goods, and the supply fleet in the North Sea, leaving CO_2 emissions from most processing industries and fisheries untaxed as before. The base-tax on mineral oil was introduced in 2000, in principle for all use and industries, but still there are several exceptions. As an adjustment towards more rigid state aid rules determined by the EFTA Surveillance Authority (ESA), from 2003 onwards the CO_2 tax only covers the use of petrol, auto diesel oil and mineral oil (except fisheries), and CO_2 emissions from offshore petroleum activities. In autumn 2005 the Government also proposed a trading system with allowances of CO_2 gas emissions. The system is similar to the European system, but emissions covered by the CO_2-tax are exempted. Together with the greenhouse-tax these mechanisms will cover about 70% of Norway's total greenhouse gases.

C3.3 Data

Fuel taxes to be used in the different scenarios in this study are shown in Table C3.1. The Norwegian fuel taxes comprise several elements; a "basic tax," CO_2 tax, SO_2 tax and NO_x tax. The first three are levied per liter fuel and the latter is based on emission weight. However, as noted above, there are several amendments and exemptions to these. Until 2013 fishing was fully exempted from the basic and CO_2 taxes, and distant water fishing was also exempted from the sulphur taxes. The NO_x system is even more complicated. Vessels with installed engine power less than 750 kW are fully exempted. The other vessels pay a reduced rate to an organization that financially supports emission reduction projects on vessels.

It is noteworthy that for firms that are subject to full taxation, the Norwegian rates are considerably higher than both the EU quota price and the Stern optimal quota price.

Table C3.1: Norwegian CO2 and energy taxes, current EU quota price on CO2 and optimal CO2 quota price forecasted in year 2100, EUR/tonne CO2 and EUR/1,000 liter fuel

	EUR/tonnes CO_2	EUR/1,000 liter fuel
Basic tax 2011	48.27	*120.68*
CO_2 tax 2011	29.47	*73.68*
NOx tax 2011		116.91
EU CO_2 quota price 2009	*13.6*	34.01
Optimal CO_2 quota price year 2100 (Nordhaus (2007)	*63.6*	159.02

Note: The *italic* numbers are known. Recalculation between the two units is made with an average CO2 -efficiency of engines of 2.5 kilo CO2 per liter fuel.

Source: Stern (2006), Nordhaus (2007) and the Norwegian Ministry of Finance.

Information on the physical and economic characteristics of the selected vessel groups has been obtained from the annual "Profitability study on fishing vessels," published by the Directorate of Fisheries. By the end of 2010 the Norwegian fishing fleet consisted of 6,309 vessels, of which 4,157 had an income from fishing of more than NOK 50,000 (EUR 6,250) and were defined as active vessels. A total of 741 vessels were in the range between 11 and 15 m, of which 694 (94%) were active. In total 1,731 vessels were entered as the "Profitability study" population of the Directorate of Fisheries (2012). For vessels between 11 and 15 m, income in 2010 had to be at least NOK 838,000 (EUR 104,750) to enter the study, while vessels above 15 m needed earnings more than double that sum (above EUR 209,380).

The coastal vessels we address here consist of the 342 vessels in the Profitability study, with a "statutory" access right between 11 and 15 m, and with fishing income in 2010 of more than EUR 104,750. At the end of 2010, roughly 500 vessels had such a permit. Hence, about 70% of the permit owners fulfilled the income demands of the “Profitability study”. These vessels belong mainly to the three northernmost counties (Finnmark, Troms and Nordland), and have an average crew of 2.5 men. Cod is the main target species, constituting 47% of the catch value in 2010, followed by saithe (13%), haddock (8%) and monkfish (8%). In 2010 their shares of the total Norwegian catch volume and value were 3 and 5%, respectively. The average age of the vessels is 21.3 year (built in 1988) and engine power of 276 hP (203 kW). Of the 8,376 employees in the whole fleet in 2010 (according to the “Profitability study”) 855 (10%) obtain their income in the coastal vessel group on which we focus.

The cod trawler group consists of vessels with a license to fish for cod, haddock and saithe with trawl. Many of the vessels have an additional license to fish for shrimp, and in the last three years a small group of vessels – of up to three – with only a shrimp trawl license (not cod) have been included. Many cod trawlers are under ownership of the fish processing industry, by exemption from the Participation Act, which states that owners of fishing vessels should be active fishermen, in order to stabilize the raw material supply to the fish processing industry, and to be independent of the seasonality of the coastal fleet landings. The cod trawler group consisted of 44 vessels in 2010, less than the half of the number in 2001 (102) due to heavy restructuring in this group. As for the catch, cod is also the most important species for these vessels, constituting 36% of catch value, followed by saithe (29%), haddock (19%) and shrimp (8%). Their shares of the national catch volume and value were 21 and 10%, respectively. That year the average cod trawler was 17.3 years old (built 1992), 52.8 m long, had a gross tonnage (GT) of 1,485 and an engine of 3,850 HP (2,830 kW).

Table C3.2: Physical and economic data for selected Norwegian fleets, 2010

	Coastal 11–15 m	Ocean trawl > 30 m
Physical data		
Full-time employment	855	1,791
Number of vessels	342	44
Physical assets (EUR Million)	66.7	366.7
No. of days at sea per vessel	196	299
Fuel consumption (1,000 liter)	8,702	112,496
Share of national landing value (%)	11.1	22.0
Main stocks[1]	Cod (IIa2)	Cod (IIa2,Ib)
	Saithe (IIa2)	Saithe (IIa2,Ib,IVa)
	Haddock (IIa2)	Haddock (IIa2,Ib)
	Monkfish (IIa2)	Shrimp (IIa2, Ib)
Share of main stocks of value (%)	75	92
Account data (EUR Million)		
Turnover	80.4	348.3
Fuel costs	4.7	51.1
Salary	35.7	106.0
Other operating costs	27.7	100.1
Capital costs	4.3	20.7
Depreciation	6.1	37.2
Salary per FTE (EUR/year)	33,000	65,000
Opportunity cost		
Salary (EUR/year) – Alternative A	47,272	47,272
Salary (EUR/year) – Alternative B[2]	41,755	59,185
Capital (%)	6	6

Note: 1. Numbers and letters refer to the stock in the specified ICES area in the Northeast Atlantic Ocean. 2. Equals the fleet average crew earning in 2010.

Sources: Landings Statistics from the Norwegian Directorate of Fisheries and Account Statistics from Fiskeridirektoratet (2011). Salary Alternative B, see Nielsen *et al.*, 2012, footnote 9.

Biological information about the main stocks is obtained from relevant ICES working group reports and summarized in table C3.3. The stocks are generally considered in very good shape, with spawning stock sizes far higher than precautionary approach levels. Fishing mortalities are also generally considered to be appropriate compared to MSY levels.

With stocks that are above SSBpa-level we have encountered some problems in the bioeconomic model and have employed actual 2010 levels as SSBmax in the model.

Table C3.3: Actual spawning stock biomass, spawning stock which offers the largest renewable catches and fishing mortality levels, tonnes

	Spawning stock biomass			Fishing mortality compared to MSY-level
	Actual 2010	Maximum	SSBpa	
Cod:				
Northeast Arctic (I, II)	1,364,000	1,364,000	460,000	Appropriate
Saithe:				
North Sea (IV, IIIa, VI)	248,000	554,000	200,000	Appropriate
Northeast Arctic (I, II)	383,000	587,000	220,000	Undefined
Northeast Arctic Haddock (I, II)	349,000	349,000	80,000	Appropriate

Source: ICES (2012).

C3.4 Results

C3.4.1 Current situation

As Norwegian fisheries to date are exempted from fuel taxation, introducing such taxation will have a negative impact on profits. In table C3.4 we have calculated how profits and resource rents would be influenced if the different scenarios' fuel taxation was employed in the fishery in 2010, without allowing the vessels any adaptation measures. For both the coastal vessels and trawlers, introducing the national fuel taxes results in negative profits, while the other scenarios have less impact on the profits.

Table C3.4: Introducing fuel taxes in the current situation

	Current profit				Current resource rent			
	No fuel tax	National fuel taxes imposed	EU CO_2 tax imposed	Stern tax imposed	No fuel tax	National fuel taxes imposed	EU CO_2 tax imposed	Stern tax imposed
Coastal 11–15m	1.9	-0.8	1.6	0.5	2.2	-0.5	1,9	0,8
Ocean trawl >30m	33.2	-1.8	29.4	15.3	53.2	18.2	49.4	35.3
Total	35.1	-2.6	31	15.8	55.4	17.7	51.3	36.1

Parameter estimates of the production function

The model employs separate Cobb-Douglas production functions with landings as a function of effort (fishing days) for each stock and vessel group. The functions are calibrated setting maximum yield corresponding to calculated effort at SSBmax, and current yield corresponding to current effort. The results are summarized in table C3.5.

Table C3.5: Calibrated Parameter Values of the Production Function

	Coastal 11–15 m	Ocean trawl > 30 m
Parameter a:		
Cod:		
Northeast Arctic (I, II)	670	9,225
Saithe:		
North Sea (IV, IIIa, VI)	.	5,575
Northeast Arctic (I, II)	347	7,550
Norteast Arctic Haddock (I, II)	136	5,829
Parameter b:		
Cod:		
Northeast Arctic (I, II)	0.050	0.0191
Saithe:		
North Sea (IV, IIIa, VI)	.	0.0125
Northeast Arctic (I, II)	0.0085	0.0323
Norteast Arctic Haddock (I, II)	0.0032	0.0125

Note.: a and b are calibrated on the basis of landings = a*E*e-(b*E) with landings in tonnes and 1,000 days at sea.

The model investigates the effects of taxing fuel through four scenarios as described below. The results of optimizing fleet size and structure, with respect to both profits and resource rent, through the model are also compared with the current situation.

Scenarios:

0. Baseline – current profit and resource rent (=2010).
1. Maximization of profit and resource rent in current situation.
2. Maximization of profit and resource rent with current energy and CO_2 tax structure imposed on fisheries.
3. Maximization of profit and resource rent with current CO_2 quota prices imposed on fisheries.
4. Maximization of profit and resource rent with predicted CO_2 quota prices in 2100 (according to Nordhaus) imposed on fisheries.

C3.4.2 Profit maximization

Table C3.6 shows the results for long-run optimization of profits for the various fuel tax scenarios. For comparison, we have included current figures for relevant variables. Comparing profits among the scenarios, we find relatively small differences. The highest profits at 1.4 billion Euro are, as expected, found when there are no fuel taxes. As the Norwegian taxes are the highest among the scenario alternatives, scenario 2 has the lowest profits, but only reduced by about 14% compared to no taxation.

First and foremost, the model proposes a large reduction in effort ranging from 49 to 56% for both vessel groups and all scenarios. This yields corresponding reductions in fuel consumption, CO_2 emissions and employment.

Table C3.7 presents more details about aspects of the optimized fishing fleet with current figures also included for comparison. As for profits, there are relatively small differences among the tax scenarios concerning revenues, landings and effort. There are also small differences in fuel efficiency and catch per day. Compared with the current situation, we find a large decrease in the value of landings. Fuel efficiency improves by 15% for the coastal vessels and 19% for the trawlers. Catch per day increases by about 25% for both vessel groups.

Table C3.6: Long run effects of fuel taxes on *profit*; number of vessels, effort, fuel consumption, CO2 emissions and employment.

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Profit, EUR Million					
Coastal 11–15m	1.9	14.4	13.8	14.2	13.6
Ocean trawl >30m	33.2	83.1	73.5	81.5	75.9
TOTAL	35.1	97.4	87.3	95.7	89.5
Number of vessels					
Coastal 11–15m	342	158	149	157	153
Ocean trawl >30m	44	23	19	22	21
TOTAL		181	168	179	174
Effort change					
Coastal 11–15m		-54%	-56%	-54%	-55%
Ocean trawl >30m		-49%	-56%	-50%	-53%
TOTAL		-53%	-56%	-53%	-55%
Fuel consumption, m^3					
Coastal 11–15m	8,702	4,023	3,793	3,997	3,904
Ocean trawl >30m	112,496	57,584	49,648	56,648	53,357
TOTAL		61,607	53,441	60,645	57,261
CO_2 emissions					
Coastal 11–15m	21,755	10,058	9,483	9,994	9,759
Ocean trawl >30m	281,240	143,960	124,121	141,619	133,393
TOTAL		154,019	133,604	151,613	143,152
Employment, full-time equivalents					
Coastal 11–15m	855	395	373	393	384
Ocean trawl >30m	1,791	917	790	902	849
TOTAL		1,312	1,163	1,295	1,233

Table C3.7: Long-run effects of fuel taxes on *profit*; revenues per liter, value of landings, landed volume, days at sea and volume per day at sea

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Revenue per liter used, EUR					
Coastal 11–15m	9.2	10.6	10.7	10.6	10.6
Ocean trawl >30m	3.1	3.7	3.8	3.7	3.7
TOTAL		4.1	4.3	4.2	4.2
Value of landings, million EUR					
Coastal 11–15m	80.4	42.6	40.5	42.4	41.5
Ocean trawl >30m	348.3	212.6	188.2	209.8	199.8
TOTAL		255.2	228.7	252.2	241.3
Volume (1,000 tonnes) of main species					
Coastal 11–15m	52.6	29.8	28.4	29.7	29.1
Ocean trawl >30m	238.0	150.5	133.9	148.6	141.8
TOTAL		180.4	162.4	178.3	170.9
Days-at sea					
Coastal 11–15m	67,032	30,992	29,218	30,792	30,070
Ocean trawl >30m	13,156	6,734	5,806	6,625	6,240
TOTAL		37,726	35,024	37,417	36,310
Volume (tonnes of main species) per day at sea					
Coastal 11–15m	0.8	1.0	1.0	1.0	1.0
Ocean trawl >30m	18.1	22.4	23.1	22.4	22.7
TOTAL		4.8	4.6	4.8	4.7

C.3.4.3 Resource rent results

Table C3.8 and table C3.9 show the results for maximizing resource rent. The results are similar with respect to all effort and consumption variables. Rents for the coastal vessels are slightly higher than profits, whereas rents for the trawlers are considerably higher in all scenarios except for no fuel taxes.

Table C3.8: Long-run effects of fuel taxes on *resource rent*; number of vessels, effort, fuel consumption, CO2 emissions and employment

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4.Stern quota price
Resource rent EUR Million					
Coastal 11–15m	2.2	14.4	14.1	14.4	13.8
Ocean trawl >30m	53.2	91.8	77.0	90.1	84.0
TOTAL	55.4	106.3	91.2	104.5	97.8
Tax revenue			18.0		
Number of vessels					
Coastal 11–15m	342	159	150	158	154
Ocean trawl >30m	44	25	21	24	23
TOTAL	382		171	182	177
Effort change					
Coastal 11–15m		-53%	-56%	-54%	-55%
Ocean trawl >30m		-44%	-52%	-45%	-48%
TOTAL		-52%	-55%	-52%	-54%
Fuel consumption, m^3					
Coastal 11–15m	8,702	4,050	3,818	4,024	3,929
Ocean trawl >30m	112,496	62,799	54,018	61,761	58,117
TOTAL	121,198	66,849	57,836	65,784	62,046
CO_2 emissions					
Coastal 11–15m	21,755	10,124	9,544	10,059	9,823
Ocean trawl >30m	281,240	156,998	135,046	154,402	145,293
TOTAL	302,995	167,122	144,590	164,461	155,116
Employment, full-time equivalents					
Coastal 11–15m	855	398	375	395	386
Ocean trawl >30m	1,791	1,000	860	983	925
TOTAL	2,646	1,398	1,235	1,379	1,311

Table C3.9: Long-run effects of fuel taxes on *resource rent*; revenues per liter, value of landings, landed volume, days at sea and volume per day at sea

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Revenue per liter used, EUR					
Coastal 11–15m	9.2	10.6	10.7	10.6	10.6
Ocean trawl >30m	3.1	3.6	3.7	3.6	3.7
TOTAL		4.1	4.2	4.1	4.1
Value of landings, million EUR					
Coastal 11–15m	80.4	42.9	40.7	42.6	41.8
Ocean trawl >30m	348.3	227.9	201.8	224.9	214.2
TOTAL	428.7	270.8	242.5	267.5	255.9
Volume (1,000 tonnes) of main species					
Coastal 11–15m	52.6	30.0	28.6	29.9	29.3
Ocean trawl >30m	238.0	160.8	143.2	158.8	151.6
TOTAL	290.6	190.9	171.8	188.7	180.9
Days-at sea					
Coastal 11–15m	67,032	31,195	29,407	30,994	30,266
Ocean trawl >30m	13,156	7,344	6,317	7,223	6,797
TOTAL	80,188	38,539	35,724	38,216	37,063
Volume (tonnes of main species) per day at sea					
Coastal 11–15m	0.8	1.0	1.0	1.0	1.0
Ocean trawl >30m	18.1	21.9	22.7	22.0	22.3
TOTAL		5.0	4.8	4.9	4.9

C3.4.4 Sensitivity analysis

A sensitivity analysis has been undertaken to obtain knowledge about the effect of errors in the parameters of the production function. For simplicity, we have only analysed three changes to the parameters and only for scenario 1 and profit maximization.

The results of the sensitivity analysis are shown in table C3.10. The parameter estimates have a relatively large impact on the results, especially parameter a. This is expected from the specification of the production function.

Table C3.10: Sensitivity analysis:Effects on profits, number of vessels, fuel consumption and effort

	Originally calibrated values of a and b	K1:parameter a decreasing by 25%	K2: parameter b increasing by 25%	K3: parameter b decreasing by 25%
Profit, EUR Million				
Coastal 11–15m	14.4	7.7	13.2	15.9
Ocean trawl >30m	81.8	42.9	74.3	95.1
TOTAL	96.2	50.6	87.5	111.0
Number of vessels				
Coastal 11–15m	158	111	143	178
Ocean trawl >30m	23	16	20	26
TOTAL	181	127	163	204
Fuel consumption, m^3				
Coastal 11–15m	4,023	2,830	3,640	4,532
Ocean trawl >30m	57,584	40,496	50,755	67,213
TOTAL	61,607	43,326	54,395	71,745
Change in effort				
Coastal 11–15m	-54%	-67%	-58%	-48%
Ocean trawl >30m	-49%	-64%	-55%	-40%
TOTAL	-53%	-67%	-58%	-47%

The vessel groups differ somewhat in which stocks they exploit. Among the major stocks included in the study, the only difference is that trawlers also exploit saithe in the North Sea. It is interesting to investigate how the modelled optimal fleet is influenced if we assume that the vessels exploit the same stocks. We have therefore excluded saithe in area IV for the major trawl stocks, and run the model for profit maximum in Scenario 1.

The results are shown in table C3.11. The changes only slightly influence the results, the most notable change being reduced profits for the trawlers.

Table C3.11: Profit maximizing results for scenario 1 with only same stocks included in analysis

	Profit	Effort change	Catch Cod	CatchHaddock	Catch Saithe
Coastal 11–15m	115	-54%	17.8	3.8	8.3
Ocean trawl >30m	594	-48%	53.2	35.7	38.6
TOTAL	710	-53%	71	39.5	46.9

C3.5 Discussion

Introducing fuel taxes in the current Norwegian fisheries will clearly reduce profits as fishing vessels to a large extent are exempted from such taxation. The results of the bio-economic model utilized in this paper suggests that allowing the fleet to adjust effort levels optimally will yield considerably increased profit and resource rent even if fuel use is taxed. This will also result in considerably less fuel use and emissions.

The effect of allowing optimal capacity, however, dwarfs the effect of introducing fuel taxation.

The analytic conclusion that both fleets should be about halved has to be interpreted with great caution, as there are uncertainties and simplifications in the modelling.

This analysis has focused on two extremes, related to the short term and the long term. The short-term accounting approach has calculated the fuel tax effects on vessel profitability by simply adding this as an additional cost, while keeping other costs and revenues constant. Thus, substitutability and adaptation are neglected. The long-term analysis is, as noted above, based on strong simplifications of biology, of vessel characteristics and of adaptation possibilities. However, based on the best judgement of the authors of this case study, the overall conclusions are that a fuel tax increase in fisheries in the short run will hamper profitability, whereas in the long run the resource rent will depend more on the general management success of the cod fisheries than on reasonable fuel taxes. Resource rent is affected by the fuel tax regime, but less so than by overall good fisheries management.

References

Armstrong, C.W., A. Eide, O. Flaaten and K. Heen (2012). The Norwegian Northeast Arctic cod fishery. In: OECD Rebuilding fisheries. Paris.

Birk- Mortensen (2009), EU CO_2 kvotemarkedet – facts and implications. Information, 23/1-2009.

International Council for Exploration of the Sea/ICES (2010), Report from the Advisory Committee of Fisheries Management, available at http://www.ices.dk/indexfla.asp

Nielsen, M., O. Flaaten and S. Waldo (2012). Management of and Economic Returns from Selected Fisheries in the Nordic Countries. Marine Resource Economics 27, 65–88.

Nordhaus, E. (2007), The Stern Review on the Economics of Climate Change, Yale University.

Stern, N. (2006), Review on the Economics of Climate Change, Cambridge University Press.

Williams, JH. & S. Hammer (2000) "The Norwegian Fisheries: An Unregulated Common Property Resource in Transition by the Introduction of Quotas, Closed Access and the Industry's User-right Perception", in Sutton, R. (ed.) Use of Property Rights in Fisheries Management. Proceedings of the FishRights99 Conference, Freemantle, Western Australia. 11–19 November 1999. Fisheries Technical Paper 404/1. FAO, Rome; Italy. Pp. 192–7. See: ftp://ftp.fao.org/docrep/fao/009/x7579e/x7579e03.pdf

C4. Iceland

Jónas Hallgrimsson, University of Iceland

C4.1 Introduction

Close to thirty species of fish are caught in considerable quantity in Icelandic waters. Three species in the model runs, as well as four vessel segments, are included in the Icelandic case for the Fuel Model, in order to study the effects of fuel taxation and emissions pricing on maximum profit and resource rent in fisheries.

The species selected for the model runs are cod, haddock and saithe, which are the three main species, both in volume and value, of demersal fish caught by Icelandic vessels. All three species are normally caught by a variety of vessel types, ranging from small handline vessels, mid-size gillnetters, longliners and Danish seiners to large freezing trawlers. The reason for this wide variety of vessel types is, firstly, the relatively even distribution of these species around Iceland and the surrounding area, and, secondly, the nature of Iceland's fisheries management system. Iceland operates an individual transferable quota (ITQ) system in the fisheries relevant to this study. The government decides yearly (actually the fishing year which runs from end of August each year) total allowable catch (TAC) for each species, based on scientific advice. The fisheries that own quotas decide how to catch fish, with what type of gear and vessel, and when within the quota year. The quotas are transferable so quota holders trade their quotas (ITQs) in the marketplace to reach their goals of profit maximization.

Some restrictions exist though on ITQ trading. The system is split into two sections. First, the small scale vessels that use handline or long-line form a separate quota section. Second, all larger vessels constitute another ITQ system. Trade between the two is heavily restricted. Further, a small portion of the system, the so-called Coastal-fishing, falls outside the ITQ system. Independent of the ITQ system there are some biological fisheries management measures, e.g. temporary bans on certain types of gear in certain zones and area closures. Nevertheless, generally speaking, there are no legal restrictions or biological factors that stipulate that these three species ought to be caught only by certain types of vessels (Icelandic Ministry of Fisheries and Agriculture n.d.).

C4.2 Current situation for different vessel segments

Four vessel segments have been chose for this project. A brief description of the different segments is presented in table C4.1:

Table C4.1: Description of segments

Segment	Description of vessels
A	Small vessels 10–200 bt
B	Medium sized trawlers >200 bt
C	Trawlers
D	Freezing trawlers

Table C4.2 shows the current status (2010) of the four vessel segments in terms of physical and accounting data. The segments are quite different as the number of vessels varies from 255 to 35 and net profits from EUR 19 to 136 million. In the calculations it is assumed that all types of vessels are at sea 250 days per year. The number of days can vary slightly between years, depending on e.g. TAC and weather. It is also assumed that all vessels employ the crews full-time.

Table C4.2: Current situation (2010) within segments

	Small vessels 10–200 bt	Medium sized trawlers >200 bt	Trawlers	Freezing trawlers
Physical data				
Full-time employment	950	750	400	550
Number of vessels	255	68	25	35
Number of days at sea per vessel	250	250	250	250
Total effort (1,000 days at sea)	64	17	6,25	8,75
Fuel consumption (1,000 l)	18,210	20,276	18,819	67,057
Account data (EUR Million)				
Value of landings	131.1	149.9	107.9	325.5
Fuel costs	11.8	13.1	12.2	43.5
Other running costs	55.6	47.4	30.1	85.0
Vessel costs	0.0	0.0	0.0	0.0
Crew share (opportunity cost)	32.7	25.8	13.7	18.9
Gross cash flow	31.1	63.6	51.9	178.2
Depreciation	4.4	6.2	2.6	27.2
Interest (opportunity cost)	7.3	7.5	4.9	15.1
Net profit	19.3	50.0	44.5	135.8
Invested capital	122.0	125.2	81.5	252.2
Opportunity cost				
Salary per employee (EUR/year)	34,000	34,000	34,000	34,000
Capital (%)	6%	6%	6%	6%

The annual opportunity cost per employee is estimated to be around ISK 5.5 million, or around EUR 34,000 and the opportunity cost of capital 6%. The actual wages for different segments, and D in particular, are much higher.

Tables C4.3 and C4.4 show the landings in 2010 as well as the value of the landings for each fish stock and vessel segment. Segment B catches the greatest total amount of fish, while segment C catches the smallest amount.

Table C4.3: Landings by vessel segment (tonnes)

	Small vessels 10–200 bt	Medium sized trawlers >200 bt	Trawlers	Freezing trawlers
Cod	40,200	49,100	37,200	37,700
Haddock	21,700	18,000	10,400	11,000
Saithe	2,400	8,000	15,300	24,100
Total	64,300	75,100	62,900	72,800

The value of the landings for the three species included in the study is the greatest for the freezer vessels, with a total landed value of EUR 112 million. Compared to the overall value of landings in table C4.2, the three fish species included in this case study are most important to vessels in segment A, representing nearly 80% of the total value of landings. The share of the three species is close to 70% for segments B and C but roughly a third for segment D.

Table C4.4: Value of landings by fish stock and vessel segment (m. EUR)

	Small vessels 10–200 bt	Medium sized trawlers >200 bt	Trawlers	Freezing trawlers
Cod	67	71	49	63
Haddock	33	24	14	18
Saithe	2	6	10	31
Total	102	101	72	112

C4.3 Icelandic carbon taxes

In 2009, so-called carbon taxes were introduced for all use of fossil fuels in Iceland. Initially, the fuel taxes were supposed to be temporary, but have since been made permanent. Table C4.5 shows the carbon tax per m^3 of fuel type for 2010 (Skattalagasafn n.d. a). The fishing vessels use gas and diesel oil with a carbon tax rate of EUR 35.5 per m^3.

Table C4.5: Carbon and energy taxes

Type of fuel	Type of tax	Fee (ISK per m^3)	Fee (EUR per m^3)
Gas and diesel oil	Carbon	5,750	35.5
Gas and diesel oil	Energy	52,770	326
Gasoline	Carbon	5,000	30.9
Gasoline	Energy	60,010	370
Fuel oil	Carbon	7,100	43.8
Petroleum gas	Carbon	630	3.9

Energy taxes are also imposed on fossil fuels and they are shown in table C4.5 above as well. The energy taxes per m^3 are significantly higher than the carbon taxes, or EUR 326 per m^3. Fishing vessels are however exempt from the energy taxes. This means that it is only carbon taxes which apply to the use of fossil fuels in the fishing industry (Skattalagasafn n.d. b).

C4.4 Scenarios

The aim of the exercise is to gauge the impact of higher fuel taxes on the fishing industry. There are four scenarios run in the model in addition to the current situation, which is referred to as the baseline. Table C4.6 shows the scenarios and the corresponding total tax per m^3 added to the fuel price:

Table C4.6: Description of scenarios

Scenario	Definition	Cost added to fuel price (EUR/m^3)
0. Baseline – Current situation	Statistics (fleet and economic)	35.5
1. Benchmark	Carbon tax	35.5
2. National taxes	Carbon and energy tax	362
3. EEX EU emission allowances	Only CO_2 costs	34.01
4. Stern	Only CO_2 costs	159.02

As mentioned before, there is currently a carbon tax on the fossil fuel used by the fishing vessels and this tax is included in the baseline. Scenario 1 includes only the carbon tax, while scenario 2 includes the carbon tax in addition to the energy tax. The total tax burden per m^3 of fuel amounts to 362 EUR per m^3 in scenario 2. Scenario 3 uses the CO_2 costs from EU emissions allowances and the total tax burden per m^3 is slightly lower than in scenario 1. Scenario 4 uses CO_2 costs from the Stern review and costs are significantly greater than in scenarios 1 and 3. All of these scenarios are considered in the model results for both the maximum profits and maximum resource rents.

C4.5 Biological information

The biological information is gathered from ICES data. The spawning stock biomass and the spawning stock biomass according to the precautionary approach are presented in table C4.7 (ICES 2012a, 2012b, 2012c).

Table C4.7: SSB today and SSB Precautionary Approach

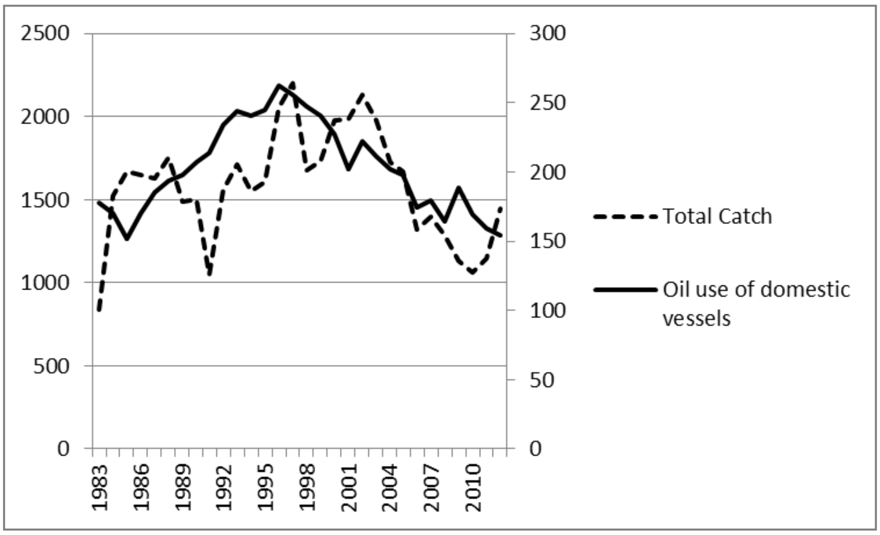
Fish stock	SSB today	SSB Precautionary approach
Cod	336,000 t	120,000 t
Haddock	91,000 t	45,000 t
Saithe	112,000 t	65,000 t

This biological information is used to calibrate the parameters in the production function.

C4.6 Historical energy use for Icelandic fishing vessels

Figure C4.1 shows the historical development of total catch as well as fuel use by Icelandic fishing vessels from 1983 to 2011. The energy used peaked in 1996 when the domestic fishing vessels used 262 kilotonnes of fuel. Total catch of all fish stocks peaked in 1997 when it amounted to nearly 2,200 thousand tonnes. The total catch can vary significantly from year to year because of changes in catches of the pelagic fish stocks. Both fuel use and total catch have decreased significantly during the last ten years or so (Statice n.d a, n.d. b).

Figure C4.1: Total catch (thousands of tonnes) (left axis) and energy use by domestic vessels (thousand tonnes) (right axis)



C4.7 Energy use forecast for Icelandic fishing vessels

The Energy Forecast Committee (which works within the National Energy Agency) provides forecasts for the energy use by, among other things, domestic fishing vessels. The forecast is based on the maximum sustainable yield, energy use per vessel type and energy use per unit of fish caught. Table C4.8 shows the total catch for the 2009–2010 fishing season, as well as the maximum sustainable yield as estimated by the Icelandic Marine Research Institute (Orkuspárnefnd 2010).

Table C4.8: Total catch by species 2009–2010 and maximum sustainable yield

	2009–2010	Maximum sustainable yield
Cod	150	290
Haddock	63	50
Saithe	30	60
Redfish	50	80
Black halibut	5	30
Other demersal species	41	60
Capelin	150	800
Herring	300	300
Blue whiting	88	200
Invertebrates	10	25
Total	887	1,895

The use of fuel for each vessel type varies significantly and is the highest for freezing trawlers, which use about twice the energy used by the smaller vessels (see table C4.9). The energy use for catching capelin, herring and blue whiting is much lower than for catching the fish stocks included in this case study (Orkuspárnefnd 2008).

Table C4.9: Energy use by vessel type

Type of vessel	Energy use in 2004 (kg fuel per kg fish)
Vessels <10 brl	0.102
Vessels > 10 brl	0.22
Vessels	0.200
Trawlers	0.356
Freezing trawlers	0.432
Caplin/herring	0.034
Blue whiting vessels	0.078

The Energy Forecast Committee has estimated coefficients for energy use for different fishing methods, shown in table C4.10. The coefficients have been estimated by local research and show great variability (Orkuspárnefnd 2008). In general, the bottom trawl is the most energy intensive large-scale fishing method while, again, catching herring, capelin and blue whiting is much less energy intense.

Table C4.10: Energy use by fishing method

Fishing method	Engine vessel(kg fuel/kg fish)
Longline	0.119
Net	0.119
Handline	0.119
Danish seine	0.153
Bottom trawl	0.297
Pelagic trawl (herring)	0.051
Pelagic trawl (chaplin)	0.027
Pelagic trawl (blue whiting)	0.075
Lobster dredge	0.361
Seine net (herring)	0.070
Seine net (chaplin)	0.017
Shrimp net	0.722
Scallop dredge	0.085
Ocean quahog dredge	0.022

The Forecasting committee assumes, in its forecasts of energy use by the domestic fishing vessels, that maximum sustainable yield will be reached in the long-run. The catches are assumed to reach maximum sustainable yield according to an S-curve where 50% of the progress from current catch to maximum sustainable yield will be achieved in 12 years (Orkuspárnefnd 2008).

C4.8 The Current situation

The profits and resource rents without the additional fuel costs (described before), before each scenario is optimized, are shown in table C4.11 below. All fisheries are still profitable and have a positive resource rent after the additional fuel costs have been subtracted.

Table C4.11: Current profits and resource rent when additional fuel costs are subtracted, million EUR

	Current profit minus additional fuel costs				Current resource rent minus additional fuel costs			
	No fuel tax	**National fuel taxes imposed**	**EU CO_2 tax imposed**	**Stern tax imposed**	**No fuel tax**	**National fuel taxes imposed**	**EU CO_2 tax imposed**	**Stern tax imposed**
Small vessels 10–200 bt	22,860	10,958	23,113	19,415	18,649	6,748	18,902	15,204
Medium sized vessels >200 bt	30,799	17,547	31,080	26,963	49,243	35,991	49,525	45,408
Trawlers	19,894	7,594	20,155	16,334	43,816	31,516	44,077	40,256
Freezer trawlers	21,490	22,338	22,421	8,804	133,412	89,584	134,343	120,726
Total	95,042	13,761	96,769	71,515	245,121	163,839	246,848	221,594

C4.9 Model results

The model is run with the data described earlier. The first step is to estimate a production function for each of the vessel segments for all three species before maximizations of profits and resource rents are determined, based on the scenarios described earlier.[9]

C4.9.1 Estimation of the parameters in the production function

The production function used in the model is:

$$Q_i = \alpha E_j e^{-bE_j}$$

where Q_i is landings for each stock and E_j is effort for each vessel group. Calibration is needed in order to estimate a and b in the equation. The

---

[9] The model is further described in the Danish case study.

numerical values for *a* and *b* for each vessel group are presented in table C4.12 below:

Table C4.12: Calibrated parameter values of the production functions

	Small vessels 10–200 bt	Medium sized vessels >200 bt	Trawlers	Freezing trawlers
Parameter a				
Cod	867	4,092	8,394	6,061
Haddock	567	1,763	2,659	2,043
Saithe	63	839	4,270	4,994
Parameter b				
Cod	0.005	0.021	0.055	0.039
Haddock	0.008	0.030	0.075	0.056
Saithe	0.008	0.034	0.089	0.068

C4.10 Profit maximization results

The results for the profit maximization are presented in tables C4.13 and C4.14. The results are similar for scenarios 1, 3, and 4. In those scenarios, maximum profits are between EUR 171–175 million. and much greater than the current profits of EUR 99 million. for the same vessel segments. The small sized vessels and trawlers exit the fishery, and all the catches are by the medium-sized vessels and freezing trawlers.

Total landings are 221–223 thousand tonnes in the three scenarios, about 50 thousand tonnes less than in the baseline. The landings by the medium sized vessels more than double in the three scenarios, from 75 thousand tonnes to approximately 165 thousand tonnes, while landings decrease by about 20% for the freezing trawlers. The value of landings is EUR 307–311 million, compared to EUR 388 million in the baseline, and the two remaining segments experience an increase in value of landings in accordance with the increase in landings.

The catch per unit of fuel and the value of catch per unit of fuel increase for the two remaining vessel segments. The efficiency metrics are much higher for the medium sized vessels, although the increases in efficiency are slightly higher than 20% for the freezing trawlers, compared to roughly 10% for the medium sized vessels when the baseline efficiency is compared to scenarios 1, 3, and 4.

The energy tax is included in scenario 2 and, consequently, maximizing the profits for the segments yields very different results and considerably lower maximum profit compared to the other three scenarios. For scenario 2, the profits are now EUR 160 million and still considerably higher than the current profits in the baseline. The composition of the vessels has also changed in scenario 2 compared to the other scenarios, as it is freezer vessels and small sized vessels which account for all the landings. Total landings are about 30% less than in the other three scenarios, and nearly half of the landings in the baseline.

The catch per unit of fuel and value of catch per unit of fuel are higher for the freezing trawlers in scenario 2 compared to the other scenarios, indicating that the higher total fossil fuel taxes create an incentive to increase fuel efficiency. The value for catch per unit of fuel and the value of catch per unit of fuel are highest for the small sized vessels compared to the other two active vessel segments in all scenarios.

Table C4.13: Results: *profit* maximization – Part 1

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Maximum profit (m. EUR)					
Small vessels 10–200 bt	23	-	62	-	-
Medium sized vessels > 200 bt	32	108	-	108	106
Trawlers	21	-	-	-	-
Freezing trawlers	24	68	98	68	65
Total	99	175	160	176	171
Total landings (thousand tonnes)					
Small vessels 10–200 bt	64	0	71	0	0
Medium sized vessels > 200 bt	75	166	0	166	164
Trawlers	62	0	0	0	0
Freezing trawlers	73	58	82	58	56
Total	275	223	154	224	221
Value of landings (m. EUR)					
Small vessels 10–200 bt	102	0	113	0	0
Medium sized vessels > 200 bt	101	223	0	224	221
Trawlers	72	0	0	0	0
Freezing trawlers	72	88	126	88	86
Total	388	311	239	312	307
Catch per unit fuel (kg catch per l fuel)					
Small vessels 10–200 bt	3.531		4.407		
Medium sized vessels > 200 bt	3.704	4.099		4.093	4.115
Trawlers	3.342				
Freezing trawlers	1.086	1.337	1.401	1.335	1.346
Value of catch per unit fuel (EUR per l fuel)					
Small vessels 10–200 bt	5.60		6.97		
Medium sized vessels > 200 bt	5.00	5.52		5.51	5.54
Trawlers	3.84				
Freezing trawlers	1.67	2.04	2.14	2.04	2.06

The remaining vessel segments, when profits are maximized in scenarios 1, 3, and 4, are identical for the three segments as freezing trawlers and medium sized vessels catch all the fish. The total number of vessels varies between 156 and 158 vessels for the three scenarios, which is a great reduction from the baseline number of vessels, 383. Similarly, the fuel consumption is approximately 82–84,000 m^3 and about 50,000 m^3 less than in the current baseline situation. The accompanying CO_2 emissions are 204–210 thousand tonnes in the scenarios, compared to more than 300 thousand tonnes in the baseline.

The number of vessels in scenario 2 increases significantly compared to the other scenarios, with 257 vessels compared to approximately 157, but fuel consumption and the accompanying CO_2 emissions are considerably lower, i.e., 75,000 m^3 of fuel and 187 thousand tonnes of CO_2.

Table C4.14: Results: *profit* maximization – Part 2

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Number of vessels					
Small vessels 10–200 bt	255	0	227	0	0
Medium sized vessels > 200 bt	68	136	0	136	134
Trawlers	25	0	0	0	0
Freezing trawlers	35	22	31	23	22
Total	383	158	257	159	156
Days at sea					
Small vessels 10–200 bt	63,750	0	56,667	0	0
Medium sized vessels > 200 bt	17,000	33,879	0	34,043	33,501
Trawlers	6,250	0	0	0	0
Freezing trawlers	8,750	5,615	7,684	5,645	5,449
Total	95,750	39,495	64,351	39,688	38,950
Effort change					
Small vessels 10–200 bt		-100%	104%	-100%	-100%
Medium sized vessels > 200 bt		168%	-100%	168%	168%
Trawlers		-100%	-100%	-100%	-100%
Freezing trawlers		19%	102%	19%	19%
Fuel consumption (1,000 l)					
Small vessels 10–200 bt	18,210	0	16,186	0	0
Medium sized vessels > 200 bt	20,276	40,408	0	40,603	39,958
Trawlers	18,819	0	0	0	0
Freezing trawlers	67,057	43035	58885	43262	41759
Total	124,362	83,443	75,071	83,866	81,717
$C0_2$ emissions (tonnes)					
Small vessels 10–200 bt	45,525	0	40,466	0	0
Medium sized vessels > 200 bt	50,690	101,021	0	101,508	99,894
Trawlers	47,048	0	0	0	0
Freezing trawlers	167,643	107,587	147,212	108,156	104,398
Total	310,905	208,608	187,678	209,664	204,292

C4.10.1 Resource rent maximization results

The model results for the maximum resource rents are presented in tables C4.15 and C4.16. When determining the maximum resource rents, opportunity wages and capital costs are compared to actual wages and interest payments in the profit maximization calculations.

According to the model, the maximum resource rents for scenarios 1, 3, and 4 are quite similar, or between EUR 305 and 317 million. All the trawlers and medium sized vessels exit the fishery, and the number of small sized vessels stays close to the current number. The number of freezing trawlers increases significantly, or roughly doubles.

Total fuel consumption increases from 124,000 m^3 in the baseline to roughly 150–156,000 m3 in scenarios 1, 3, and 4. Moreover, CO_2 emissions increase from about 320,000 to 374–390,000 tonnes. The increase in fuel consumption and CO_2 emissions can be explained in part by the increase in number of freezing trawlers from 35 in the baseline to 69–72 in the scenarios.

Scenario 2 yields different results from the other three scenarios as the resource rent is considerably lower, EUR 275 million, compared to the other scenarios, but still higher than EUR 249 million in the baseline

The carbon taxes, which fishing vessels already pay, yield a tax revenue equal to EUR 0.7 million, according to the model, while the energy and carbon tax will yield a EUR 6 million tax revenue in scenario 2.

Table C4.15: Results – *Resource rent* maximization – Part 1

	Current situation	**1. No fuel taxes**	**2. National exemptions removed**	**3. EU 2009 CO_2 quota price**	**4. Stern quota price**
Maximum resource rent (m. EUR)					
Small vessels 10–200 bt	19	70	65	70	69
Medium sized vessels > 200 bt	50	-	-	-	-
Trawlers	45	-	0	-	-
Freezing trawlers	136	245	204	247	236
Tax revenue	-	0,7	6	-	-
Total	249	316	275	317	305
Total landings (tonnes)					
Small vessels 10–200 bt	64	80	75	80	79
Medium sized vessels > 200 bt	75	0	0	0	0
Trawlers	62	0	0	0	0
Freezing trawlers	73	139	127	139	136
Total	275	219	202	220	216
Value of landings (m. EUR)					
Small vessels 10–200 bt	102	127	124	127	125
Medium sized vessels > 200 bt	101	0	0	0	0
Trawlers	72	0	0	0	0
Freezing trawlers	72	214	195	215	210
Total	388	341	319	342	335
Catch per unit fuel (kg catch per l fuel)					
Small vessels 10–200 bt	3.531	4.389	4.469	4.390	4.409
Medium sized vessels > 200 bt	3.704				
Trawlers	3.342				
Freezing trawlers	1.086	1.017	1.107	1.014	1.037
Value of catch per unit fuel (EUR per l fuel)					
Small vessels 10–200 bt	5.60	6.94	7.43	6.94	6.97
Medium sized vessels > 200 bt	5.00				
Trawlers	3.84				
Freezing trawlers	1.67	1.57	1.70	1.56	1.60

The fuel consumption in all scenarios is greater than in the baseline, or about 20–25% higher in scenarios 1, 3 and 4 and about 6% higher in scenario 2 (see table 15). The catch per unit of fuel and the value of catch per unit fuel are lower in scenarios 1, 3 and 4 for the freezing trawlers compared to the baseline (table 14). The fuel efficiency is therefore decreasing for the freezing trawlers as the resource rents are maximized in those scenarios. There is a slight increase in the efficiency metrics in scenario 2 compared to the baseline.

Contrary to the decreasing fuel efficiency of the freezing trawlers, the fuel efficiency is about 25% greater for the small vessels remaining in the scenarios compared to the baseline.

Table C4.16: Results – *Resource rent* maximization – Part 2

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Number of vessels					
Small vessels 10–200 bt	255	256	234	256	251
Medium sized vessels > 200 bt	68	0	0	0	0
Trawlers	25	0	0	0	0
Freezing trawlers	35	71	60	72	69
Total	383	327	294	328	320
Days at sea					
Small vessels 10–200 bt	63,750	64,020	58,601	64,033	62,758
Medium sized vessels > 200 bt	17,000	0	0	0	0
Trawlers	6,250	0	0	0	0
Freezing trawlers	8,750	17,835	14,946	17,954	17,183
Total	95,750	81,855	73,547	81,987	79,941
Effort change					
Small vessels 10–200 bt		125%	129%	125%	126%
Medium sized vessels > 200 bt		-100%	-100%	-100%	-100%
Trawlers		-100%	-100%	-100%	-100%
Freezing trawlers		78%	79%	78%	78%
Fuel consumption (1.000 l)					
Small vessels 10–200 bt	18,210	18,287	16,739	18,290	17,926
Medium sized vessels > 200 bt	20,276	0	0	0	0
Trawlers	18,819	0	0	0	0
Freezing trawlers	67,057	136,682	114,539	137,593	131,687
Total	124,362	154,968	131,277	155,883	149,614
CO_2 emissions (tonnes)					
Small vessels 10–200 bt	45,525	45,716	41,847	45,726	44,815
Medium sized vessels > 200 bt	50,690	0	0	0	0
Trawlers	47,048	0	0	0	0
Freezing trawlers	167,643	341,705	286,346	343,982	329,219
Total	310,905	387,421	328,193	389,708	374,034

C4.10.2 Sensitivity analysis

The sensitivity analysis is conducted in order to estimate how sensitive the results are to changes in the calibrated parameters a and b in the production function. Three additional profit maximization calculations are conducted for scenario 1 where:

1. K1: a is reduced 25%, b held constant.
2. K2: b is increased 25%, a held constant.
3. K3: b is reduced 25%, a held constant.

The results for the sensitivity analysis are presented in tables C4.17 and C4.18. By changing the two parameters, medium sized vessels exit while small sized vessels enter the fishery. The total maximum profits are lower for K1 and K2 while higher for K3. In all scenarios, the profits are higher for the freezing trawlers and nearly double when *b* is reduced 25% in K3. The maximum profits in scenario 2 are about the same as in the baseline.

Table C4.17: Sensitivity analysis – Part 1

	Originally calibrated values of a and b	K1:parameter a decreasing by 25%	K2: parameter b increasing by 25%	K3: parameter b decreasing by 25%
Maximum profit (m. EUR)				
Small vessels 10–200 bt	-	37	60	77
Medium sized vessels > 200 bt	108	-	-	-
Trawlers	-	-	-	-
Freezing trawlers	68	77	103	124
Total	175	115	164	201
Total landings (tonnes)				
Small vessels 10–200 bt	0	44	66	90
Medium sized vessels > 200 bt	166	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	58	57	80	106
Total	223	101	146	196
Value of landings (m. EUR)				
Small vessels 10–200 bt	0	69	105	143
Medium sized vessels > 200 bt	223	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	88	87	122	162
Total	311	156	227	304
Catch per unit fuel (kg catch per l fuel)				
Small vessels 10–200 bt		3.446	4.243	4.457
Medium sized vessels > 200 bt	4.099			
Trawlers				
Freezing trawlers	1.337	1.060	1.311	1.415
Value of catch per unit fuel (EUR per l fuel)				
Small vessels 10–200 bt		5.44	6.71	7.04
Medium sized vessels > 200 bt	5.52			
Trawlers				
Freezing trawlers	2.04	1.62	2.01	2.16

The efficiency metrics are sensitive to the changes in the parameters in the production function, as there is a significant reduction in the values for the freezing trawlers when *a* is reduced.

Table C4.18: Sensitivity analysis – Part 2

	Originally calibrated values of a and b	K1:parameter a decreasing by 25%	K2: parameter b increasing by 25%	K3: parameter b decreasing by 25%
Number of vessels				
Small vessels 10–200 bt	0	178	219	284
Medium sized vessels > 200 bt	136	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	22	28	32	39
Total	158	206	250	323
Days at sea				
Small vessels 10–200 bt	0	44,580	54,668	71,029
Medium sized vessels > 200 bt	33,879	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	5,615	6,979	7,920	9,755
Total	39,495	51,559	62,588	80,784
Effort change				
Small vessels 10–200 bt	-100%	111%	102%	105%
Medium sized vessels > 200 bt	168%	-100%	-100%	-100%
Trawlers	-100%	-100%	-100%	-100%
Freezing trawlers	19%	93%	95%	103%
Fuel consumption (1.000 l)				
Small vessels 10–200 bt	0	12,734	15,615	20,289
Medium sized vessels > 200 bt	40,408	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	43035	53487	60698	74760
Total	83,443	66,220	76,313	95,049
CO_2 emissions (tonnes)				
Small vessels 10–200 bt	0	31,834	b	50,722
Medium sized vessels > 200 bt	101,021	0	0	0
Trawlers	0	0	0	0
Freezing trawlers	107,587	133,717	151,745	186,901
Total	208,608	165,551	190,783	237,622

The results of the sensitivity analysis are structurally different from the previous calculations of maximum profits in the sense that the freezing trawlers and small vessels do all the catching instead of the freezer vessels and medium sized vessels. This structural change shows how sensitive the results are to different value of the parameters used in the production function.

C4.11 Conclusions

According to the model, greater profits and resource rents can be achieved by structuring the fisheries differently and having two vessel segments catching all the fish. The possible gains are significant.

The carbon and energy taxes imply a cost increase for the vessel segments. Therefore, the maximum profits and resource rents are lower in the scenarios where the total fossil fuel taxes are higher. In general, the results from scenarios 1, 3, 4 are similar, indicating that the vessel segments included are not sensitive to slight cost increases. Scenario 2, however, yields different results, as should be expected, with lower maximum profits and resource rents.

The fuel consumption is reduced when profits are maximized, while there is an increase in fuel consumption when resource rents are maximized. The great increase in use of freezing trawlers is most likely the explanation for this fuel increase.

The efficiency metrics, catch per unit of fuel and value of catch per unit of fuel, increase in the profit maximization scenarios and hence greater total taxes on fuel lead to greater energy efficiency. On the other hand, the efficiency metrics only decrease slightly when resource rents are maximized for the freezing trawlers. This indicates that the tax burden is outweighed by the possible increases in resource rents from catching more fish. The efficiency metrics increase for the small sized vessels when resource rents are maximized. This clearly shows the structural difference in the challenges faced by the different vessel segments when the resource rent is maximized.

References

Icelandic Ministry of Fisheries and Agriculture (n.d.). Fisheries Management http://www.fisheries.is/management/fisheries-management/

ICES (2012a) Cod in Division Va (Icelandic cod) http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/had-iceg.pdf

ICES (2012b) Saithe in Division Va (Icelandic saithe) http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/sai-icel.pdf

ICES (2012c) Haddock in Division Va (Icelandic haddock) http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/cod-iceg.pdf

Skattalagasafn (n.d. a). Kolefnisgjald á kolefni af jarðefnauppruna. http://skattalagasafn.is/?log=129.2009.1

Skattalagasafn (n.d. b) Vörugjald af olíu, gjaldskylda og fjárhæð gjalds. http://skattalagasafn.is/?log=87.2004.1

Statice (n.d. a) Energy http://www.statice.is/Statistics/Manufacturing-and-energy/Energy

Statice (n.d. b) Catch and value of catch http://www.statice.is/Statistics/Fisheries-and-agriculture/Catch-and-value-of-catch

Orkuspárnefnd (2008) Eldsneytisspá. http://www.os.is/media/eldsneyti/Orkuspa2008-50.pdf

Orkuspárnefnd (2010) Almennar forsendur orkuspáa. http://www.os.is/media/orkusparnefnd/ALMF2010.pdf

C5. Greenland

Daniel Schütt, Statistics Greenland; Max Nielsen, University of Copenhagen; Frank Jensen, University of Copenhagen

C5.1 Introduction

The purpose of this paper is to identify how much the contribution from shrimp fishing to the Greenlandic economy can be increased, and to discuss how that potential can be realised. Furthermore, the purpose is to analyse the economic effect on the shrimp fishery of introducing fuel taxes to limit CO_2-emissions. The situation today is compared to the best possible socio-economic situation in the long run and the questions addressed are: How much can the fishery potentially increase its contribution to the Greenlandic GDP? How can this potential be achieved? Are land-based shrimp factories affected? What are the implications for employment in the sector? How will the possible introduction of climate change motivated fuel taxes affect the economy of the Greenlandic shrimp fishery? What is the most efficient policy tool to reduce CO2-emissions in the shrimp fishery? The methodological basis is bio-economic modelling, based on data from Statistics Greenland and the Greenlandic Ministry of Fisheries, Hunting and Agriculture.

Knowledge of socio-economic optimal exploitation of Greenlandic shrimp stocks is important, since it reveals whether and to what extent shrimp fisheries can improve their contribution to GDP. It is shown that the resource rent in the fishery was EUR 34.0 million in 2010, corresponding to 22% of the landing value. This is on a reasonable level compared to other Nordic countries, where Nielsen *et al*. (2010) estimate resource rents in pelagic fisheries to be on average 32% of the landing value, and where Nielsen, Flaaten and Waldo (2012) estimate resource rents in demersal fisheries to be -22% in Norway, 28% at the Faroe Islands and 30% in Iceland.[10] An important explanation for the reasonable size of the resource rent in the Greenlandic shrimp fishery is the presence of the relatively well-working individual transferable quota regulation.

---

[10] A negative resource rent indicates that remuneration of labour is higher in sectors other than fisheries, and/or that a higher rate of return of capital can be achieved in other sectors. Under such circumstances, using labour and/or capital in other sectors would, from a socio-economic point of view, be better. Therefore, the resource rent becomes less than zero.

The analysis also estimates the maximum resource rent to be EUR 89.7 million (59% of the landing value). This maximum resource rent is around the same level as in the above mentioned Nordic fisheries, where the maximum resource rents are all within the range of 43–66%. Furthermore, the World Bank and FAO (2008) estimate the difference between the maximum and current resource rents, termed "The Sunken Billons", to $50 Billion annually worldwide. Hence, according to the calculations in this paper, it appears possible to increase the GDP contribution from primary shrimp fishing by EUR 55.7 million and thereby raise the Greenlandic GDP by 4%.

The instruments to achieve this gain is to build larger shrimp stocks than the MSY biomass level recommended by biologists, and to allow the sale of shrimp quotas from the smaller in-shore vessels to production trawlers. By building the shrimp stock up to a larger size, catch per unit effort will increase at decreasing costs. TACs need to be reduced, but the contribution of the sector to GDP needs to increase. This gain, however, is only for primary fisheries and since catches from in-shore trawlers supply land-based factories, and production trawlers export the majority of their catches directly, such a policy change will affect the economy and employment at land-based factories negatively. These effects are not identified in the current paper and need to be subtracted from the above numbers, to identify the full socio-economic potential of the Greenlandic shrimp fishery. There are, however, indications that the inclusion of land-based shrimp factories will not change the result much, owing to low profitability of the land-based shrimp factories.

The relevance of analysing the effects of increasing fuel taxes comes from the desire of providing more knowledge on how to manage climate change through reduction in fuel use, preferably in a way where the effect on climate is achieved in the cheapest possible way for the society as a whole. This study focuses on the shrimp fishery, although reductions in fuel use are of equal importance in other sectors in the economy. What separates fisheries from most other sectors is that taxing fisheries might lead to reductions in fishing activities, which in turn might lead to a larger socio-economic contribution of the sector, provided that overcapacity exists. Hence, a double dividend might be achieved in the form of a positive climate effect and larger earnings in fisheries.

In section C5.2, the history, management and biology of the Greenlandic shrimp fishery are described, followed by a review of the fuel market in Greenland in section C5.3. Section C5.4 presents the data and C5.5 the bio-economic model used. Results are presented and discussed, including sensitivity analyses, in section C5.6, and section C5.7 extends the analysis with the land-based shrimp factories. Section C5.8 concludes the paper and draws policy implications.

C5.2 The Greenlandic shrimp fishery

Shrimp fishing in Greenland is very important in economic terms. In 2010 the export value of shrimp products was 52% of the total value of all exported goods and products from Greenland. The products from the shrimp industry can be divided into two main categories of products; one is boiled frozen shrimp with shell produced on-board the off-shore production trawlers. These are exported directly from the trawlers without being landed to a land-based production facility in Greenland. The second category is produced from the shrimps landed in Greenland and produced as cooked and peeled shrimps at the land-based factories.

Shrimp fishing in Greenland began in the middle of the 1970s, when the off-shore fisheries developed. In 1990 and 1996 individual transferable quotas were introduced for the off-shore and the in-shore fishery. Between 1990 and 1996 the in-shore fishery had a regulation system with transferable capacity points, which meant that new capacity was not allowed into the fishery without the same amount of capacity being taken out. From 1st January 1997, individual transferable quotas were also introduced for in-shore fisheries, implying that the same management system came into force in the two segments. This remains in force today. In this system, yearly quotas can be sold from off-shore to in-shore vessels, but not *vice versa*.

The off-shore production trawlers have an obligation to land 25% of the catches to land-based production, thereby allowing 75% of the catches to be produced on-board the vessel and exported. The shrimps are produced predominately as boiled and frozen shrimps. The reason for the obligation to land 25% of the catches is to supply the land-based industry with raw material and thereby ensure employment at land-based factories.

The in-shore trawlers have a 100% obligation to land catches. The in-shore trawlers do not have production facilities on-board, and the vessels do not have the same ability to increase the value of the product. Hence, the revenue in the two segments is very different. At the moment, there are four land-based production facilities producing cooked and peeled shrimps.

In-shore coastal licenses were originally given only to vessels under 80 tonnes (corresponding to 75 GRT/120 GT). In 2002–2003 new types of licenses were issued for the in-shore segment, which meant that three licenses were issued with a 25% obligation to land catches, thereby allowing 75% production on-board.[11]

At the moment only two of the licenses which have a quota with 25% landing obligation are being utilized by production trawlers. In this case study, the two trawlers are analysed together with off-shore trawlers, as their production cost and revenue are estimated as being more similar to the off-shore than the in-shore coastal segment.

The current legislation sets an ownership ceiling on the quota share. A company or an individual may not have control of a quota share above 33.3% in the off-shore segment, and 15% in the in-shore segment. The fishing companies are allowed to own shares in other companies, as long as they are not the majority shareholder or owner. The ownership ceiling in the in-shore fishery was increased from 10% to 15% of the quota with effect from 2012.

The technical conservation measures include restrictions such as the mesh size limit of 44 mm, the use of sorting grids to reduce the by-catch of fish and prohibition of discarding of shrimp.[12]

The Greenlandic fleet has access to several fishing areas: two are within the Greenland EEZ and others are in international waters.[13] The biological advice for these areas is given by ICES and NAFO. The Government of Greenland sets the final TAC for the Greenland EEZ.

The in-shore segment is only allowed to fish the quota at West Greenland, and the off-shore Greenlandic trawlers also focus most of their effort in West Greenland. In 2007–2011 the amount of catches of shrimps which were not made in West Greenland formed only 1% of the total catches of shrimps by Greenlandic vessels.[14]

The West Greenland shrimp stock is considered as one single population covering the whole West Greenland area (NAFO Subarea 0/1). The Greenland fishery exploits the stock in Subarea 1 (Division 1A–1F), where the Canadian fishery has been limited to Division 0A since 1981.

The separation between off-shore fishing, which has to take place beyond a three nautical mile boundary from the base line, and the in-shore fishing, which takes place within the three nautical mile boundary from

---

[11] A license with a permit of 30% production was issued earlier in 1999.

[12] 0 n 1 NIPAG 2011 NAFO SCS Doc. 11/20 Serial No. N5998.

[13] West Greenland, East Greenland and NAFO 3L. There are also fishing days in the area NAFO 3M, but they have not been utilized recently.

[14] Based on the official catches of the Greenlandic fleet from 2007-2011 in NAFO and ICES areas, *Greenland Fisheries License Control*.

the base line, is a management issue, and has its roots in an agreement reached in 2002 between representatives of the two segments.

The West Greenland quota for the Greenlandic fishery is by law separated into the two segments. 57% of the quota is allocated to the off-shore fishery, 43% to the in-shore fishery. In recent years this separation has been a little diluted as it is possible for the off-shore fishery to transfer part of its off-shore quota to in-shore vessels.

A management plan[15] for the West Greenland shrimp fishery has been adopted by the Government of Greenland, since it was a necessary prerequisite for the West Greenland shrimp fishery to be certified by the Marine Stewardship Council as a proven sustainable fishery. The management plan entailed a to-do clause; if the biological advice decreases more than 10% from year to year, which it did from 2011 to 2012. The advice for NAFO subarea 1 and 0 went down from 120,000 tonnes to 90,000 tonnes. The management plan has a recommendation based on the economic importance of the species. The TAC for 2012 was set to 105,000 tonnes, and was further reduced in 2013. The TAC set by the Government of Greenland in 2012 includes an amount allocated to the EU and a unilateral allocation of an amount to the Canadian fishery. Key figures on the shrimp stock and fishery at West Greenland are shown in table C5.1 for 2007–2012.

Table C5.1: Advice, Total Allowable Catches and catches in the West Greenland shrimp fishery, tonnes

Year	Advice	TAC	Total catches	Greenland catches[1]	In-shore	Off-shore[2]
2007	130,000	134,000	123,038	119,037	40,995	78,042
2008	110,000	127,300	132,372	128,650	45,404	83,246
2009	110,000	114,570	116,842	112,864	43,357	69,507
2010	110,000	114,570	112,065	108,138	40,702	67,436
2011	120,000	124,000	117,816	113,848	46,836	67,012
2012	90,000	105,000				

Note:

1. The reason that catches may be higher than the Total Allowable Catch is that the Greenlandic vessels have a flexibility scheme where a quota may be transferred to the following year, if the quota is not fully utilized. It is also possible to take an advance on the next year's quota, within certain rules. A license in the off-shore fishery with 1% of the quota is included in this number for 2008 and 2009. This vessel is otherwise not included in the analysis.
2. Two vessels in the in-shore segment are included in this figure, as they only have a 25% landing obligation.

---

[15] Forvaltningsplan for rejefiskeriet i Vestgrønland, June 2010, Ministry of Fisheries, Hunting & Agriculture.

From a biological point of view the main concern was previously the counting of the catches. The catches from the sea were higher than “official” catches. That was due to a management rule allowing vessels to deduct the shrimps that were scrapped when they landed their catches for production at land-based factories. This system was changed in 2011, and the catches should therefore be close to the actual harvest from the sea.

Facts on shrimp and the shrimp stocks are presented in box C5.1.

Box C5.1. Facts on northern shrimp, *Pandalus borealis*

The shrimp lives in lower waters, mostly at depths of 50 to 600 meters. The shrimp is a hermaphrodite. It starts its life as a male, and becomes sexually mature at the age of 4–5 years on average. At the age of about 6–7 years the shrimp changes sex. The biomass and the spawning stock biomass are determined on the basis of fishing surveys and other methods, such as fishing effort, catch per unit effort and catch reports. The table below shows the biological estimates from surveys carried out by the Greenlandic Institute of Natural Resources. The survey biomass is estimated (in 1,000 tonnes) by sex and is based on length-weight distributions from 2007–2011. Data for 2005–2010 was re-analysed in 2011.

Year	Males	Females	Total	Males %	Females %
2007	227.8	128.7	356.6	63.9	36.1
2008	182.6	99.5	282.1	64.7	35.3
2009	173.5	105.0	278.4	62.3	37.7
2010	222.3	122.4	344.7	64.5	35.5
2011[1]	148.5	112.0	260.5	57.0	43.0

Source: Greenlandic Institute of Natural Resources (2011).

C5.3 The fuel market in Greenland

As the population of Greenland is relatively small and spread over a large area, the cost of supplying oil to customers is high. Therefore, oil is supplied by a government owned company. The land-based oil supply can be viewed as a natural monopoly because of the high cost. This is also the case for many other supply industries such as electricity, water, and shipping. The political will ensures equal access secured both by government owned companies and through contracts between the government and companies. A contract between the government and the oil supplying company includes an obligation to supply fishing vessels below 200 Gross Register Tonnage (GRT), which include some of the in-shore shrimp trawlers. There are a few in-shore shrimp trawlers that exceed 200 GRT. Vessels larger than 200 GRT are required to buy fuel at market prices, which are set at spot prices (a day to day price).

Outside a three nautical mile line, fuel is supplied from international companies. The vessels bunker at sea, beyond the regulation of the Government of Greenland. This implies that fuel used for these vessels cannot be taxed efficiently. In 2011 the Government of Greenland introduced a minor environmental taxation on fuel, of 13.4 euro pr. m^3 fuel (1,000 litre). In the comments to the legislation, it is noted that offshore trawlers use bunkering at sea, and that the Greenlandic Company is in competition with other international companies supplying these vessels. An environment tax, if hypothetically introduced for vessels above 200 GRT, would have to develop a method to enforce and control beyond the three nautical miles and in harbours in foreign countries.

Table C5.2 shows the current Greenlandic energy tax together with the current price of CO_2 quotas for power stations and larger companies within the EU. As a measure for the long-run optimal CO_2 quota price, the CO_2 quota price identified for the year 2100 by Stern (2006) is also presented, although this price has been criticised for being unrealistically large (Nordhaus 2007).

Table C5.2. Greenlandic energy tax, current EU quota price on CO2 and optimal CO2 quota price forecasted in year 2100, EUR/tonne CO2 and EUR/m^3 (1,000 litre) fuel

	EUR/tonne CO_2	EUR/m^3 fuel
Greenlandic energy tax 2011	5.13	*13.40*
Greenlandic CO_2 tax	0	*0*
EU CO_2 quota price 2009	*13.03*	34.01
Optimal CO_2 quota price year 2100 Stern (2006)	*60.93*	159.02

Note: The *italic* numbers are known. Recalculation between the two units is made with an average CO2 efficiency of engines in Greenlandic fishing vessels of 2.61 kilo CO2 per litre fuel.
Source: European Climate Exchange (2010), Stern (2006).

The Greenlandic energy tax was 13.40 EUR/m^3 fuel in 2011. The tax in EUR/tonnes CO_2 is calculated by multiplying the tax in EUR/m^3 fuel by 2.61, with 2.61 measuring an average energy efficiency of the engines of Greenlandic shrimp vessels. The EU CO_2 quota price was EUR/m^3 fuel 34.01 in 2009, while the predicted quota price in the year 2100 is EUR/m^3 fuel 159.02. Note that the EU CO_2 quota price is considerably above the 2011 Greenlandic taxes. The prices of fuel in 2010 are used to calculate fuel consumption for the segments, as fuel costs are known from account data. In this paper, the average price of fuel is used, and there is no distinction between different types of fuel. The average prices for bunkering and the prices for the in-shore fishing are shown in table C5.3.

Table C5.3. Average gasoil prices in Greenland, EUR/m^3 fuel

	2007	2008	2009	2010	2011[1]
In-shore price set by the Greenlandic company	501	534	572	572	747
Off-shore/bunkering prices	450	612	493	497	584

Note: In-shore price includes the environment tax of 13.40 euro per m^3 fuel from January 2011.
Source: Statistical Greenland, energy and fuel price statistics.

C5.4 Data

Physical and economic data for Greenlandic shrimp fishing are shown in table C5.4.

Table C5.4. Physical and economic data for Greenlandic shrimp trawl fleets, 2010

	In-shore trawlers	Production trawlers	Total
Physical data (all vessels)			
Full-time employment	251	321	572
Number of vessels	31	9	40
No. of days at sea per vessel	168	294	196
Physical assets (EUR million)	35.8	148.6	184.5
Quota rights assets (EUR million)	7	11	18.0
Fuel consumption (m^3 fuel)	16,233	41,204	57,437
Share of national landing value (%)	17	46	64
Account data (EUR million)			
Turnover	41.2	110.0	151.2
Fuel costs	8.5	20.5	29.0
Salary	13.3	29.0	42.3
Other operating costs	13.5	34.4	47.9
EBITDA	5.9	26.1	32.0
Depreciation	5.8	7.9	13.7
Depreciation quota rights	1.6	3.5	5.0
Depreciation vessels	4.3	4.4	8.7
EBIT	0.1	18.2	18.3
Capital costs	1.5	1.4	2.87
Profit before tax	-1.4	16.8	15.4
Salary per FTE (EUR/year)	52,965	90,509	74,045
Opportunity cost			
Salary (EUR/year)	36,000	36,000	36,000
Capital (%)	6	6	6

Note: The account data is up-scaled by the total landing value in the respective segments. The in-shore segment consists of data for 86% of the total landing value for this segment. The production trawlers include accounts for 75% of the total landing value for this segment.

The full-time employment is estimated on the basis of crew members of each vessel and the number of days at sea. The number of vessels in the two segments is the active numbers of vessels. The physical assets are the cost of the fishing vessel, based on the replacement cost of the vessels, where the value of the quota rights is the asset in the accounts. The share of the national landing value is the percentage the two segments have of the total landing value of all catches made by Greenlandic fishing vessels. The salary per FTE is calculated as the salary from the account data divided by the FTE.

The opportunity cost of labour corresponds to the wage of an unskilled industrial worker on land, where the opportunity cost of capital is an indicator for the rate of return on private investments. Table C5.4 shows that the production trawlers are fully utilizing the capacity in relation to days at sea, where capacity utilisation of in-shore vessels is lower. The account data shows that the in-shore segment had a negative profit before tax in 2010, but also that the salary per FTE was higher than the opportunity cost. The production trawlers had a positive profit before tax, and the salary pr. FTE was higher than both the in-shore segment and the opportunity cost.

Table C5.5 shows the biological data for the main West Greenlandic shrimp stock, based on NAFO (2010).

Table C5.5. Biomass and fishing mortality level of shrimps in 2010 NAFO Subarea 0 and 1

	Spawning stock biomass1		Fishing mortality2
	Current	MSY	
Northern shrimp (tonnes)	122,400	110,000	Above target

Note:
1. Spawning stock is from survey biomass estimates by sex, based on length-weight distribution. The current spawning stock biomass includes only females. The spawning stock biomass corresponding to MSY is not directly mentioned in the NAFO (2010) report, but it is stated that “the current biomass is projected to be about 10% above the biomass corresponding to MSY”. Hence, the calculation is based on a spawning stock biomass of females at 110.000 tonnes.
2. The mortality caused by fishing and cod predation has been stable and below the upper limit reference (Zmsy) since 1995. With catches in 2010 projected at 138,500 tonnes, the risk of total mortality in 2010 exceeding Zmsy was estimated at about 37.5%.
Source: NAFO (2010), 0 n 1 NIPAG (2011).

The current spawning stock biomass (including females) is 122,400 and is about 10% above the spawning stock biomass corresponding to MSY of 110,000 tonnes (NAFO 2010). Thus, the current spawning stock biomass is at a sustainable size, although fishing mortality is above the target. Hence, there is a risk that the fishing mortality is not sustainable.

C5.5 Model

In this section, the contribution of shrimp fishing to the Greenlandic economy is identified as the resource rent. The resource rent is defined as:

> “The net-surplus that, at a given time, remains for the remuneration of capital and labour above the rate achieved in other businesses.”

Resource rent measures the economic return the Greenlandic society obtains from ownership of the shrimp stock. The resource rent differs from profit in private companies in that it is the excess return for society above what could have been achieved if investments were made in other sectors and if labourers worked in other sectors. The return on capital is identified for a capital stock that excludes the value of shrimp quotas, since these do not entail real value for society. Quota values remain a capital asset that needs to provide returns to private companies, but for the society it only represents a transfer that does not provide real costs and benefits. If the rate of return on capital invested in fishing is higher than if invested in other sectors, and if the salary of fishermen are higher in fisheries than in other businesses, the resource rent is positive. This implies that the shrimp fishery contributes positively to the Greenlandic economy. If remuneration of capital and labour are lower in fisheries than in other businesses, the resource rent is negative. Hence, capital and labour could be used more productively in other branches.

The resource rent includes all excess returns above what could have been achieved from the use of capital and labour in other sectors. The excess returns originate from good fisheries regulation, but also from some fishermen being better than others. Separation between the two is not possible and a distinction is not made.

The current resource rent and profit are estimated according to financial accounts in 2010, on the basis of alternative remuneration of labour given by an assessed salary of crew in land-based industries and alternative remuneration of capital, corresponding to the interest rate on government bonds. A long run bio-economic model identifies the maximum resource rent, as well as the effort/fleet reduction necessary to achieve it. The maximum resource rent is compared to the current, without analysing the transition path and time. Hence, it is assumed that the discount rate is zero, implying that the future weight is exactly like the present. Furthermore, fishing mortality is assumed sustainable today. Costs are all considered variable, because focus is on the long-run. The comparison of current and maximum resource rents yields information on how well the shrimp fishery is regulated economically, since the resource rent is exhausted under open-access and fisheries continue to the point where profit corresponds to that obtained in other activities. A maximum resource rent larger than the current reveals that shrimp fisheries can contribute more to the Greenlandic economy.

In this paper, the resource rent is identified together with profit. The calculation of resource rent and profit is compared in table C5.6.

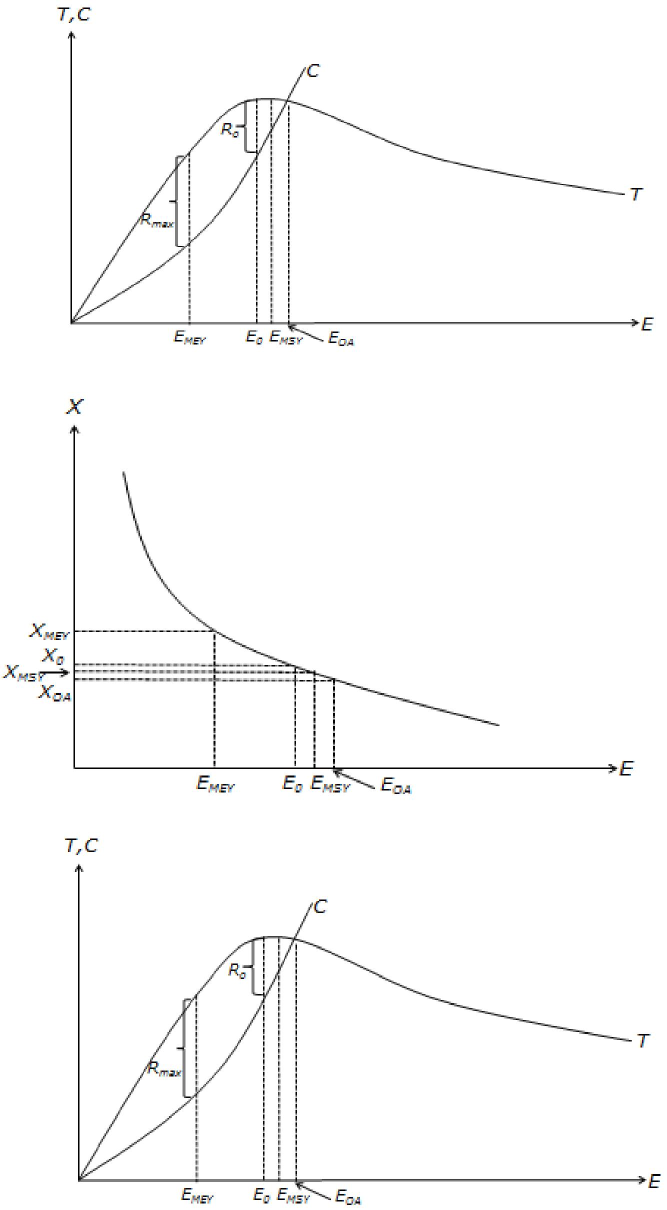
Table C5.6. Calculation of resource rent and profit

Resource rent	Profit
Turnover	Turnover
– Costs (excluding labour and capital)	– Costs (excluding labour and capital)
– Costs of labour in alternative use	– Actual costs of labour
– Costs of capital in alternative use	– Actual cost of capital
= Resource rent	= Profit

Profit is the same as resource rent, apart from the actual cost of labour and capital being used. Focus is on contribution to the Greenlandic GDP, as measured by the resource rent, since profit in the long run will always end up at a level corresponding to remuneration of capital in other businesses. The reason is that continued excess profit capitalises on the quota values. The maximum profit is identified in the current paper without subtracting costs of purchasing shrimp quotas, and in that respect is overestimated. Since these costs are only private, the maximum resource rent is determined with larger precision.

The principles of identifying the maximum and current resource rents are shown in figure C5.1, drawn to represent the Greenlandic shrimp fishery.

Figure C5.1. Long run maximum and current resource rents in fisheries



The relationship between fishing effort (E) total social cost (C) and total revenue (T) is shown in the upper diagram, and the relationship between fishing effort and biomass is shown in the lower diagram. In the upper diagram, total revenue is the product of the sustainable yield and price. Total revenue increases with fishing effort until MSY, after which it decreases in the long run owing to reduced fish stocks and overexploitation. MSY identifies the maximum sustainable catch, but all points along T are sustainable. Total social cost represents production costs of fishing with capital and labor in alternative use. Total social costs increase with effort. In the lower diagram, biomass decreases with fishing effort, since fisheries affect the shrimp stock. Effort is measured as total days at sea.

Under open access, the bionomic equilibrium is reached where total cost equals total revenue, i.e. where the T and C curves intersect. In that situation, the resource rent (total revenue minus total social cost) is zero and profit is at exactly the same level as can be obtained from using labor and capital in alternative sectors.

Optimal regulation ensures maximization of the vertical distance between total revenue and total social costs, represented by R_{max} in the figure and also known as the maximum economic yield (MEY). Effort in open access is larger than effort in MSY, which is larger than the current effort, which in turn is larger than effort in MEY. Conversely, the resource rent is largest in MEY, lower in MSY and zero under open access. In E_{MEY}, fish stocks are largest (X_{MEY}) and larger than the current biomass (X_0), which is larger than the biomass in MSY (X_{MSY}), which, in turn, is larger than the biomass under open access (X_{OA}). Not only is the resource rent largest in MEY, but the biomass is also more certain than with short-run fluctuations.

Today, the situation in the Greenlandic shrimp fishery corresponds to (E_0, X_0 and R_0). Hence, the resource rent can be increased to R_{max} in the long run by reducing effort to E_{MEY}, thereby increasing the biomass of the shrimp stock to X_{MEY}. The way to achieve the maximum resource rent is to build up a stock to X_{MEY}, larger than today, through larger reductions in the TAC than recommended by biologists.

In the following the maximum resource rent is identified for two fleet segments: the in-shore vessels and production trawlers. The calculation is made for an average vessel in each of the two fleet segments in two steps: 1) effort in both segments is reduced equally to E_{MEY}, and 2) the production trawlers are allowed to take over quotas from the in-shore vessels. The gain of letting only production trawlers survive forms part of the maximum resource rent, together with the gain of shrimp stock building. Hence, to achieve the maximum resource rent, it is necessary to both build up the shrimp stock and allow in-shore vessels to sell quotas to production trawlers.

The above method is used to identify the maximum resource rent, potentially achieved through the 2-fold change in fisheries regulation. The simultaneous introduction of fuel taxes in the shrimp fishery is also analysed. That is done under 4 alternative scenarios of fuel taxes:

1. The baseline case without fuel and energy taxes.
2. The case where fishermen pay the current CO2/energy tax.
3. The case where the existent CO2 permit price for coal, oil, natural gas and electricity in the EU is paid (European Climate Exchange 2010).
4. The case where fishermen pay the long-run equilibrium permit price in the EU identified in year 2100 (Stern 2006).

The maximum resource rent and profit are identified in all 4 scenarios. The corresponding effort adjustments, as well as CO2 and fuel consumption changes, are also identified for each fleet segment. In the first scenario no fuel/energy taxes are paid. This corresponds to the current situation. The second scenario arises when the existing fuel/energy tax is paid. Here the fishing sector pays exactly the same taxes as other industries. The existing CO2 permit price in the EU is paid in the third scenario. This corresponds to a case where the Greenlandic fishing sector hypothetically is included in the EU permit market. In the last scenario, the long-run equilibrium (year 2100) permit price is paid based on the forecasted price in Stern (2006). Here, the fishing industry is also included in the EU permit market and the long-run value of permits is the relevant cost to include.

C5.6 Results

The short-run effect of introducing fuel taxes is identified by calculating how profit, resource rent and costs, all other thing equal, are affected. That is, given the existence of an unchanged fleet size and with unchanged fishing pattern. Table C5.7 shows the short-run effects of introducing fuel taxes, together with turnover pr. litre fuel consumed, the catch pr. litre fuel consumed and fuel use per days at sea. The short run effects are calculated on the basis of financial accounts with added fuel cost from the 4 scenarios (from table C5.2).

Table C5.7. Short run effects on profit and resource rent of added fuel cost

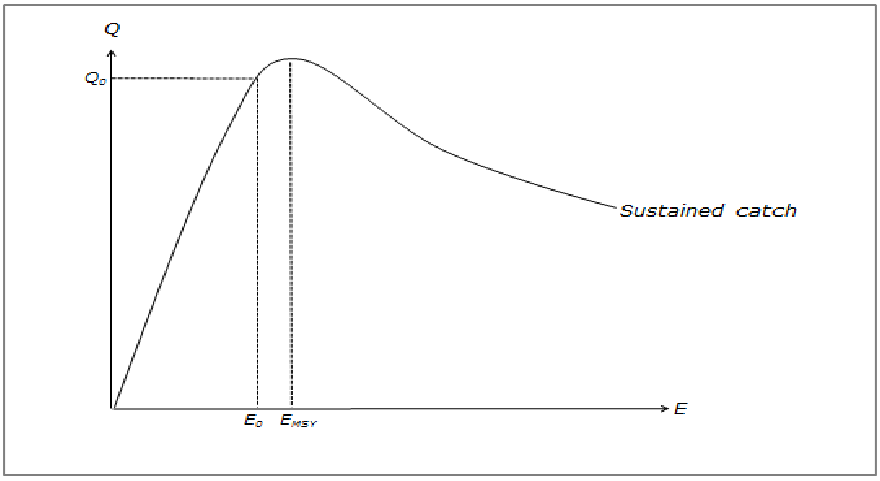
	In-shore trawlers	Production trawlers	Total
Account data			
Turnover (EUR million)	41.2	110	151.2
Fuel costs (EUR million)	8.5	20.5	29
Fuel consumption (m^3 fuel)	16,233	41,204	57,437
Share of fuel costs in turnover (%)	21	19	19
Turnover (EUR/litre fuel consumed)	2.54	2.67	2.63
Catch (kilo/litre fuel consumed)	2.51	1.66	1.90
Consumption of fuel (m^3 fuel/days at sea)	3.86	15.58	8.39
Fuel Scenarios, added cost (EUR million)			
Baseline (No tax)	0.0	0.0	0.0
National (EUR 13.4 / m^3 fuel)	0.2	0.6	0.8
EU (EUR 34.01 / m3 fuel)	0.6	1.4	2.0
Stern (EUR 159.02 / m^3 fuel)	2.6	6.6	9.1
Profit in fuel scenarios (EUR million)			
Baseline (No tax)	-1.4	16.8	15.3
National (EUR 13.4 / m^3 fuel)	-1.6	16.4	14.7
EU (EUR 34.01 / m^3 fuel)	-2.0	15.8	13.8
Stern (EUR 159.02 / m^3 fuel)	-4.0	12.3	8.3
Resource Rent in fuel scenarios (EUR million)			
Baseline (No tax)	3.7	30.2	34.0
National (EUR 13.4 / m^3 fuel)	3.5	29.7	33.2
EU (EUR 34.01 / m^3 fuel)	3.2	28.8	32.0
Stern (EUR 159.02 / m^3 fuel)	1.1	23.7	24.8

Catch per liter fuel is largest for the in-shore trawlers, the cost share of fuel is lowest for production trawlers, and turnover per liter fuel is largest for production trawlers. Hence, which fleet segment depends most on fuel differences among indicators.

For all 4 scenarios, calculating the effect on profit for the offshore segment in the short run, a reduction in the added fuel cost is included, as it is calculated as a crew share. In the maximum added fuel cost scenario (scenario 4), the added fuel cost for the in-shore segment is EUR 2.6 million, and for production trawlers EUR 6.6 million. An added cost would be a very hard additional cost for the in-shore trawlers in the short run, as they already have a negative profit in the baseline. The production trawlers are more able to accommodate the added cost.

The long-run effects of introducing fuel taxes and optimizing the Greenlandic shrimp fishery are analysed in the bio-economic model described in section C5.5. First, parameters need to be calibrated. Afterwards, given the calibrated parameters, the maximum resource rent and profit are identified. The production function has the shape shown in figure C5.2.

Figure C5.2. Calibrating the production function



The production function has the following functional form $Q = aEe^{-bE}$, where Q is landings, E is effort and e is the natural number. This functional form is found by identifying parameter a and b separately for each of the two fleet segments. That is done for each fleet segment knowing initial total days at sea, initial catch and effort corresponding to MSY. Effort in MSY is further found assuming that since the MSY biomass level 10 is% lower than the current biomass, effort in MSY is 10% higher than current effort, owing to the inverse relationship between effort and biomass (shown to the right of figure C5.1). The identified parameters are shown in Table C5.8.

Table C5.8. Calibrated parameter values of the production function for northern shrimp

Parameter	In-shore trawlers	Production trawlers
a	19,241	62,338
b	0.173	0.338

Note: *a* and *b* are calibrated with landings in tonnes and 1,000 days at sea.

Given the calibrated parameter values, the maximum resource rent and profit are estimated for the four scenarios. The results of maximising the resource rent are shown in table C5.9, with the current situation being for 2010.

Table C5.9. Long run maximum *resource rent* for fuel taxes in 4 scenarios

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Maximum resource rent (EUR million)					
In-shore trawlers	3.7	0	0	0	0
Production trawlers	30.2	89.7	89.3	88.7	85.4
Fuel tax revenue	.	.	0.6	.	.
Total	34.0	89.7	89.9	88.7	85.4
Number of vessels					
In-shore trawlers	31	0	0	0	0
Production trawlers	9	9	9	9	9
Total	40	9	9	9	9
Effort change (% change in days at sea)					
In-shore trawlers	-	-100	-100	-100	-100
Production trawlers	-	2.7	2.4	1.7	-0.9
Total	-	-65.2	-65.3	-65.5	-66.4
Fuel Consumption (1,000 m^3)					
In-shore trawlers	16.2	.	.	.	.
Production trawlers	41.2	42.6	42.5	42.2	41.2
Total	57.4	42.6	42.5	42.2	41.2
CO_2 emission (1,000 tonnes)					
In-shore trawlers	42	.	.	.	.
Production trawlers	108	111	111	110	107
Total	150	111	111	110	107
Full-time employment					
In-shore trawlers	251	0	0	0	0
Production trawlers	321	332	331	329	321
Total	572	332	331	329	321
Terminal catch (1,000 tonnes)					
In-shore trawlers	40.7	0	0	0	0
Production trawlers	68.6	98.5	98.4	98.1	97.9
Total	109.3	98.5	98.4	98.1	97.9
Turnover (EUR million)					
In-shore trawlers	41.2	0	0	0	0
Production trawlers	110.0	158.1	158	157.5	157.1
Total	151.2	158.1	158	157.5	157.1
Catch (kg)/litre fuel					
In-shore trawlers	2.51	0	0	0	0
Production trawlers	1.66	2.31	2.31	2.32	2.38
Total	1.90	2.31	2.31	2.32	2.38
Turnover (EUR)/litre fuel					
In-shore trawlers	2.54	0	0	0	0
Production trawlers	2.67	3.71	3.71	3.73	3.82
Total	2.63	3.71	3.71	3.73	3.82

The results are conclusive. There is a large increase in the resource rent, if fishing effort is reduced to the MEY-level. Furthermore, effort moves between the two segments, corresponding to quotas being transferred from in-shore to production trawlers. In scenario 1, where the resource rent is maximised without any changes in fuel taxes, the resource rent increases from EUR 34.0 million to EUR 89.7 million, a gain of EUR 55.7

million. That corresponds to an increase from 22 to 59% of the landing value. This gain implies that all in-shore vessels need to leave the shrimp fishery and let the production trawlers take over their quotas. The total fishing activity is reduced substantially. The 31 in-shore vessels leave the sector and the 9 production trawlers have only a minor increase in effort of 2.7%. Total fuel consumption and total CO_2-emissions fall by 26%, owing to the in-shore segment disappearing. Fuel consumption and CO_2-emissions from production trawlers increase a little. Total catch is reduced from 109,300 to 98,500 tonnes, a continued 10% reduction. Full-time employment is reduced from 572 to 332, i.e. by 240. The large resource rent gain can only be achieved with that reduced employment.

The results of maximising profit are shown in table C5.10. The current situation is again for 2010.

Table C5.10. Long run maximum *profit* for fuel taxes in 4 scenarios

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Maximum profit (EUR million)					
In-shore trawlers	-1.4	0	0	0	0
Production trawlers	16.8	81.1	80.8	80.3	77.4
Total	15.3	81.1	80.8	80.3	77.4
Number of vessels					
In-shore trawlers	31	0	0	0	0
Production trawlers	9	9	9	9	8
Total	40	9	9	9	8
Effort change (% change in days at sea)					
In-shore trawlers	-	-100	-100	-100	-100
Production trawlers	-	-4.3	-4.5	-5.2	-7.4
Total	-	-67.5	-67.6	-67.8	-68.6
Fuel Consumption (1,000 m^3)					
In-shore trawlers	16.2	.	.	.	.
Production trawlers	41.2	39.7	39.7	39.4	38.4
Total	57.4	39.7	39.7	39.4	38.4
CO_2 emission (1,000 tonnes)					
In-shore trawlers	42	.	.	.	.
Production trawlers	108	104	104	103	100
Total	150	104	104	103	100
Full-time employment					
In-shore trawlers	251	0	0	0	0
Production trawlers	321	310	309	307	299
Total	572	310	309	307	299
Terminal catch (1,000 tonnes)					
In-shore trawlers	40.7	0	0	0	0
production trawlers	68.6	95.9	95.9	95.5	94.6
Total	109.3	95.9	95.9	95.5	94.6
Turnover (EUR million)					
In-shore trawlers	41.2	0	0	0	0
Production trawlers	110.0	153.9	153.8	153.3	151.8
Total	151.2	153.9	153.8	153.3	151.8

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Catch (kg)/litre fuel					
In-shore trawlers	2.51	0	0	0	0
Production trawlers	1.66	2.41	2.42	2.43	2.46
Total	1.90	2.41	2.42	2.43	2.46
Turnover (EUR)/litre fuel					
In-shore trawlers	2.54	0	0	0	0
Production trawlers	2.67	3.87	3.88	3.89	3.95
Total	2.63	3.87	3.88	3.89	3.95

From table C5.10 it appears that profit in scenario 1 increases from EUR 15.3 million to EUR 81.1 million, corresponding to a EUR 65.8 million increase. Hence, profit can increase substantially, just as the resource rent. It is, however, underlined that the gain is calculated with the inclusion of the amounts that, due to improved fisheries regulation, capitalise on quota values. This implies that the maximum profit in that respect is overestimated. This overestimation is not made for the maximum resource rent, since capitalisation only represents a transfer, not a cost, for the society.

The policy instrument to achieve the large resource rent gain is fisheries regulation. That is, “to avoid a situation where there are too many fishermen to fish too few fish” and to ensure that only the most efficient fishermen continue in the sector. The combined use of two policy instruments points towards a way of achieving the gain: 1) to build a larger shrimp stock in the long run than advised by biologists, through a persistently larger reduction in the TAC than currently advised, and 2) to allow in-shore vessels to sell shrimp quotas to production trawlers.

The effects of fuel taxes in the short run are EUR 0.8–9.1 million, as seen in table C5.7. The effect is largest in the Stern scenario (scenario 4) and corresponds to 6% of the landing value, which is of importance for the shrimp industry in the short run, where profit is reduced correspondingly. In the long run, however, fisheries can adapt by optimising their activities to the new fuel price level, focussing on e.g. fuel use and fuel efficiency of engines. Such options are not included in the calculation. Furthermore, if fuel taxes are introduced together with a shrimp stock building/quota trade liberalisation policy, the extra fuel costs are reduced and by far counterbalanced by the gain from the combined policy. Although the maximum resource rent and profit in the shrimp fishery are smaller with fuel taxes (scenario 2–4) than without (scenario 1), such a policy leads to a large gain in resource rent and profit, even with the most extreme fuel taxes (scenario 4).

The long-run effects of fuel taxes, introduced together under the shrimp stock building/quota trade liberalisation policy, are negligible. Fuel use and CO_2-emissions from the shrimp fishery are reduced by 26–31% without any fuel taxes, where the reduction is 29–33% in the most extreme case of fuel taxes (scenario 4). Therefore, a shrimp stock building/quota trade liberalisation policy is a better instrument with which to achieve reductions in fuel use/CO_2-emissions from the shrimp fishery.

The results are achieved based on the parameters in table C5.8. In order to verify whether the results are decisively affected by these parameters, sensitivity analyses are performed. Since results are relatively alike in all the four scenarios, sensitivity analysis is only performed for scenario 1. The results are shown in table C5.11.

Table C5.11. Sensitivity analyses of parameter a and b for scenario 1

	Current situation	**Resource rent**			**Profit**		
		-25%	**Unchanged**	**+25%**	**-25%**	**Unchanged**	**+25%**
Parameter a							
Resource rent (EUR million)	34.0	55.5	89.7	.	.	.	.
Profit (EUR million)	15.3	.	.	.	48.8	81.1	.
Number of vessels	40	8	9	.	7	9	.
CO2-emissions (1,000 tonnes)	150	98	111	.	89	104	.
Parameter b							
Resource rent (EUR million)	34.0	76.8	89.7	104.8	.	.	.
Profit (EUR million)	15.3	.	.	.	67.3	81.1	97.0
Number of vessels	40	11	9	8	10	9	8
CO2-emissions (1,000 tonnes)	150	128	111	99	117	104	94

The largest reduction in the resource rent appears when parameter a is reduced by 25%, and becomes EUR 55.5 million. Hence, even when a is set at a 25% lower level, a considerable gain over the current resource rent of EUR 34 million remains. The results also depends on parameter b, although the effect of a 25% reduction remains lower than for the 25% reduction in a. Therefore, the identified socio-economic gains are robust in relation to the calibrated parameters.

The maximum resource rent and profit are identified under certain assumptions. First, the model applied compares current resource rent/profit with the maximum achievable in the long run. Thereby, the fact that achieving the long run maximum resource rent/profit might take a long (or short) time is neglected. If society weights today's earning over future earning (if the social discount rate is positive), the maximum resource rent/profit is overestimated. The overestimation is, however, smaller the shorter the transition period and the smaller the discount rate.

Second, the maximum resource rent and profit are calculated assuming that the fishing mortality is sustainable initially, knowing full well that in 2010 there was a 37.5% risk of the fishing mortality leading to the shrimp stock falling below the MSY-level (of not being sustainable). As a consequence, there is a probability of 62.5% that the fishing mortality will not lead to the shrimp stock falling below the MSY-level (of being sustainable). If the fishing mortality is not at a sustainable level initially, the maximum resource rent and profit might be overestimated.

Third, the maximum profit is identified including the gain of better fisheries regulation that capitalises on quota values, and without subtracting the funding costs of purchasing the extra quota necessary to achieve the gain. The maximum profit (but not the maximum resource rent) is overestimated in that respect. Finally, the calculation is made for an average vessel in the two fleet segments, and it is found that the inshore trawlers all need to leave the sector. In reality, however, the most efficient inshore trawlers might end up continuing, and the least efficient production trawlers might risk going out of business.

Despite the fact that the assumptions induce uncertainty about the exact size of the maximum resource rent, it is of a size that makes it unlikely that a large gain to society cannot be achieved. That is also true from a logical point of view. Firstly, because the resource rent of inshore vessels is close to zero, whereas it is high for production trawlers. The two fleet segments fish on the same shrimp stock, and letting production trawlers take over shrimp quotas from in-shore vessels logically induces a gain. Secondly, since TACs are set on the basis of biological advice on minimum stock levels, and since fisheries economic theory finds that MEY in single species fisheries, such as the shrimp fishery, is achieved in the long run at a higher stock level than corresponding to MSY, a resource rent gain from shrimp stock building result. Today (2010) the biomass is above the size of the biomass corresponding to MSY. According to this analysis, however, increasing the stock size even more in the long run, through continued TAC reductions, leads to cost falling more than turnover, thereby increasing the resource rent. Third, studies from other countries find a maximum resource rent in fisheries around the same level as in the Greenlandic shrimp fishery (43–66%). Therefore, despite uncertainty about the exact size of the maximum resource rent, it is unlikely that a large gain cannot be achieved.

C5.7 Extension with land-based factories

The results reveal that there are significant values to be gained in the long run, by building the shrimp stock up and by allowing quota trade between the two fleet segments. Even if fuel taxation is included, it remains possible to achieve considerable higher resource rent and profit. That gain might, however, be overestimated if significant losses appear in land-based factories. That is an obvious risk, since production trawlers earn the main part of their income from direct export. Hence, if production trawlers buy quotas from in-shore vessels and produce 75% onboard, which is exported directly, supply to the land-based factories will fall considerably.

A full socio-economic analysis needs to take the economics of both vessels and land-based activities into account. That has not been done here. What are compared here are resource rents and profits between two fleet segments at different stages in the value chain. Value added in sea-based processing is included in the profit of the production trawlers. The in-shore trawler segment does not have value added production, implying that the costs are mainly related to fishery. To fully compare the two segments, it is more reasonable for the in-shore trawlers to include the value chain for the land-based production.

The account data for land-based shrimp production is shown in table C5.12. The account items are divided between the two fleet segments according to their landed catches. Landed catches are divided by a factor of 3.1, compared to exported products. The account data is based on one of the two operators producing shrimps, and as they operate two factories each, each account item is scaled up to cover the whole industry.

Table C5.12. Physical and economic data for Greenlandic shrimp fishing and processing industry, 2010[1]

	Activities generated by in-shore trawlers			Activities generated by off-shore trawlers			Total
	Vessels	Factories	Total	Vessels	Factories	Total	
Physical data (factories)							
Full-time employment	251	244	495	321	96	417	912
Number of vessels	31		31	9		9	40
No. of days at sea per vessel	168		168	294		294	196
Physical assets (EUR million)	35.8	29.8	66	148.6	11.7	160	226
Quota rights assets (EUR million)	7		7	11		11	18
Fuel consumption (1,000 m^3)	16.2	1.6	17.8	41.2	0.6	41.8	59.6
Account data (EUR million)							
Turnover	41.2	64.6	65.3	110.0	23.2	119.2	184.5
Value of landed product		40.6			14		
Fuel costs	8.5	0.9	9.4	20,5	0.4	20.8	30.3
Salary	13.3	9	22.3	29.0	3.5	32.6	54.9
Other operating costs	13.5	10.7	24.2	34.4	4.2	38.6	62.8
EBITDA	5.9	3.5	9.4	26.1	1.1	27.2	36.6
Depreciation	5.8	2.2	8.0	7.9	0.9	8.8	16.7
- Buildings or factory		2.2	2.2		0.9	0.9	3.0
- Quota rights	1.6		1.6	3.5		3.5	5.0
- Vessels	4.3		4.3	4.4		4.4	8.7
EBIT	0.1	1.3	1.4	18.2	0.2	18.4	19.8
Capital costs	1.5	0.4	1.8	1.4	0.1	1.6	3.4
Profit before tax	-1.4	1	-0.4	16.8	0.1	16.9	16.5
Salary per FTE (EUR/year) fishing	52,965		52,965	90,509		90,509	74,045
Salary per FTE (EUR/year) prod.		36,902	36,902		36,954	36,954	36,917
Salary per FTE (EUR/year) avg.			45,042			78,177	60,197

Note: 1. Account data for factories are based on production at two factories, scaled up to the amount landed by the two segments. The amount landed is the official catches landed, and not the full harvest that could have been landed. Account data are divided between the two segments based on the landing values and assuming that production costs per kg. shrimp are the same for the two segments.

Source: Own calculations based on annual accounts from Polar Raajat A/S and from Royal Greenland A/S.

It appears that even when including production in land-based factories, profit is not significantly changed; not for in-shore or for production trawlers. Thus, the gain for the Greenlandic society from the shrimp stock building/quota trade liberalisation policy seems to hold when taking potential losses in land-based factories into account.

The result indicates that there is very likely a considerable gain to obtain if politically desired. The full gain will be achieved through the simultaneous shrimp stock building and liberalisation of shrimp quota trade policy, without any changes in the production permits of the production trawlers. However, provided that a certain level of production in land-based factories remains politically desirable, quota trade liberalisation can be followed by a reduced production permit for the large trawlers. That might lead to a gain, although the full potential gain will not be realised.

The disadvantage of such a policy is reduced employment; 240 full-time employed in fisheries and a maximum of 244 in the factories. Hence, alternative employment opportunities are important when such a policy is considered. Provided that employment becomes needed in other sectors, reducing employment in shrimp fishing/processing remains an option. Under such hypothetical circumstances, the shrimp stock building/quota liberalisation policy yields a double gain: larger profit/resource rent in shrimp fishing *and* releasing employment from in-shore fishing and processing plants to other sectors that need labour.

Introducing a simultaneous shrimp stock building/quota liberalisation policy might raise allocation issues, since gains accrue mainly to fishermen (both the ones that leave fisheries and the ones that continue). The government can obtain a share of this gain through taxation.

C5.8 Conclusions

This paper has analysed the potential gain in resource rent of improved fisheries regulation, and estimated the economic effect of introducing fuel taxes to limit CO_2-emissions in the shrimp fishery. It is found that the shrimp fishery can contribute EUR 55.7 million more than today, corresponding to 4% of the Greenlandic GDP. The instruments to achieve the gain are 2-fold: 1) to build a larger shrimp stock in the long run than advised by biologists, and 2) to allow in-shore vessels to sell shrimp quotas to production trawlers.

The gain is identified by considering only primary fishing. The socio-economic contribution of land-based shrimp processing has been neglected, implying that different levels in the value chain are compared. Hence, there is a need to confirm/reject the result in a bio-economic analysis with inclusion of both primary shrimp fishing and land-based processing. Judging by the figures for 2010, however, there is no indication that the result will change by incorporating land-based processing. The reason is low profitability in land-based processing.

An introduction of fuel taxes will affect earnings in the primary fishery negatively in the short run by EUR 0–9 Million. If fuel taxes are introduced together with a shrimp stock building/quota trade liberalisation policy, their long run CO_2-effect will be largely non-existent, as compared with the policy without fuel taxes. The policy will reduce CO_2-emissions from the sector by 26–29%, and the presence/absence of fuel taxes will not affect that significantly. Hence, a shrimp stock building/quota trade liberalisation policy will reduce CO_2-emissions more efficiently than fuel taxes.

The full socio-economic gain, together with the positive climate effect, can only be achieved if the production permits for large trawlers remain unchanged. If the production permits are reduced, a resource rent gain can still be achieved, without the reduction in supply of raw materials to land-based processing becoming too large. But the resource rent gain will be less than the identified EUR 55.7 million.

Liberalisation of quota trade without changing production permits will affect employment in in-shore fisheries and land-based processing negatively. That is a problem in the short run if no alternative employment opportunities exist. In the long run, however, such a policy might release labour to other sectors. That might be particularly important if/when other sectors in Greenland demand extra labour.

The results are achieved under certain assumptions. Despite the fact that all assumptions are selected to represent reality, they induce uncertainty about the exact size of the gain. Still, it is not likely that a large gain cannot be achieved.

References

European Climate Exchange (2010). ECX EUA Futures Contract: Historic Data European Climate Exchange. http://www.ecx.eu/EUA-Futures, accessed 10/02/22

Forvaltningsplan for rejefiskeriet i Vestgrønland (2010), Ministry of Fisheries, Hunting and Agriculture, June 2010.

Nielsen, M., P. Andersen, L. Ravensbeck, F. M. Laugesen, J. Andersen, D. M. Kristoffersen, S. Reithe, J. Nilssen and H. Ellefsen (2010), Samfundsøkonomisk afkast af pelagiske fiskerier i Nordøstatlanten, Nordisk Ministerråd Tema Nord 2010:573.

Nielsen, M., O. Flaaten and S. Waldo, (2012), Management of and Economic Returns from Selected Fisheries in the Nordic Countries, Marine Resource Economics, 27 (1), 64–88, March 2012.

0 n 1 NIPAG 2011 NAFO SCS Doc. 11/20 Serial No. N5998 and ICES CM 2011/ACOM:14, NAFO/ICES Pandalus Assessment Group Meeting, 19–26 October 2011.

Nordhaus, W. (2007), Critical Assumptions in the Stern Review on Climate Change. Science 317:201–202.

North Atlantic Fishery Organisation/NAFO (2010), Advice for Northern shrimp Subarea 0 and 1, available at http://www.nafo.int/

Stern, N. (2006), Review on the Economics of climate Change, Cambridge University Press.

World Bank and Food and Agriculture Organization (2008). The Sunken Billions. The Economic Justification for Fisheries Reform. Agriculture and Rural Development Department. The World Bank. Washington.

C6. Faroe Islands

Hans Ellefsen, Faroese Ministry of Fisheries

C6.1 Introduction

This paper is part of the project "Effect of a fuel taxation in Nordic fisheries" funded by the Nordic Council of Ministers, Working Group for Fisheries. All the Nordic countries including Greenland and the Faroe Islands are contributing case studies within the same analytical framework as the Faroese case study. The project is being led by senior researcher Staffan Waldo, AgriFood Economics Centre, SLU and Lund University, Sweden, and includes researchers from each of the countries. The Faroese case is presented by Hans Ellefsen, PhD, of the Ministry of Fisheries; the paper reflects solely the view of the author, and not in any way that of the employer institution.

This paper analyses the long-term economic effects of increasing fuel prices in the Faroese demersal fishery. In the process, we find the conditions under which the Faroese demersal fishery could contribute most to the Faroese GDP. The methodical basis for this analysis is a bio-economic model developed by Nielsen, Flaaten and Waldo (2012). The model is based on data from the private accounting firm called NOTA and the Faroese Ministry of Fisheries.

The relevance of analysing the effect of increasing the fuel price through taxation comes from the desire to obtain more knowledge on how to manage climate change through reduction in fuel use, preferably in a way where the effect on climate is achieved as cheaply as possible for the society as a whole. This study focuses on the demersal fishery, although reductions in fuel use are of equal importance in other sectors of the economy. What separates fisheries from most other sectors is that taxing fisheries might lead to reductions in fishing activities, which lead to a larger socio-economic contribution of the sector, provided that overcapacity exists initially. Hence, a double dividend might be achieved in the form of a positive climate effect and smaller catches with less effort. Such a double dividend is not expected in most other sectors.

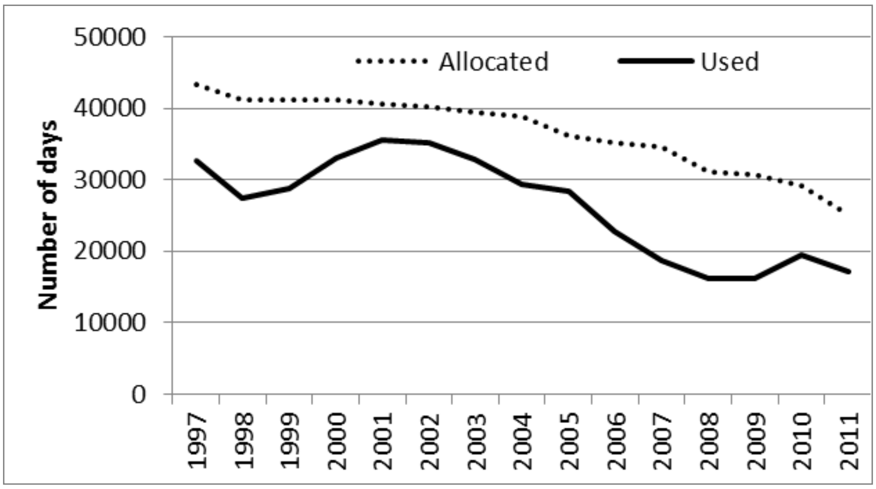
The structure of this paper is as follows. First, we consider the history and management of the demersal fleet of the Faroes. Second, we consider the data and the model, and finally we consider the results.

C6.2 History and management of the demersal fleet on the Faroe Islands

The Faroe Islands (Faroes) have a high degree of dependency on fisheries. In economic terms the fisheries sector accounts for almost 20% of GDP (OECD 2011), and almost all exports of goods from the Faroes are fish products (97% in 2010). But the fisheries sector is diverse and consists of fish farming, fish factories and fishing. The fishing part is divided into the pelagic fishery, distant water fishery, and the local demersal fishery. Historically, demersal fish stocks have been an important part of the total fishery, but in recent years the demersal stocks have declined (cf. figure C6.3), and the other fisheries have become more important in terms of landing values (cf. table C6.1).

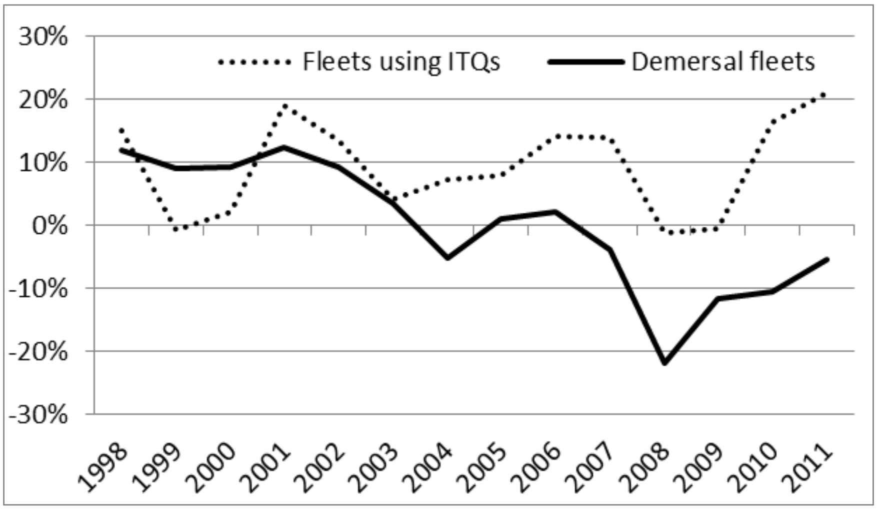
The history of Faroese fishing of demersal species goes back more than 100 years. The main demersal stocks around the Faroes are cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and saithe (*Pollachius virens*). Until the beginning of the nineties, the fishing in the Faroe area was only regulated by licenses. Following the crash in the main species in the early 1990s (cf. figures C6.3–C6.4), an ITQ (individual transferable quota) system was introduced by creditors, but that was in place for only two years. After the main stocks miraculously returned in the mid-1990s, the ITQ system was abolished and the current fishing-days system was introduced in 1996. This system regulates the effort instead of the catch, and is coupled with gear restrictions in a large system of closed areas on the Faroe shelf. The fishing days are in principle transferable, but there has not been an effective market for fishing days since its introduction (cf. figure C6.1). From about 1996 to about 2002, this system was successful. However, this system has not been successful for the last 10 years, either economically (cf. figure C6.2) or biologically (cf. figures C6.3–C6.4). Figure C6.1 shows that the used days are much lower than the allocated days, and could this be a contributing factor to the bad economic performance.

Figure C6.1: Allocated and used days in the fishing-days system



Source: NOTA (2012) and Fiskidaganevndin (2012).

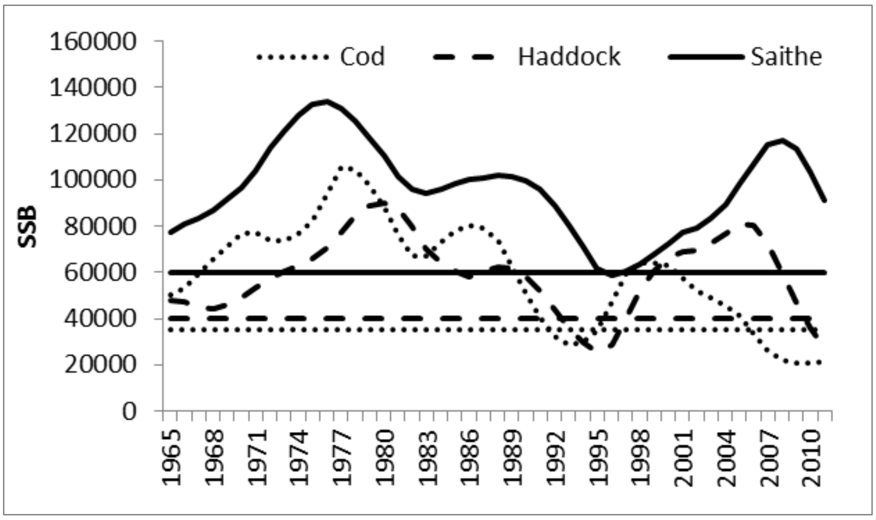
Figure C6.2: The profit margin (profits as percentage of revenue) for the demersal fleet using the fishing-days system, and Faroese fleets using ITQs (i.e. pelagic and distant water fishing)



Source: NOTA (2012) and Fiskidaganevndin (2012).

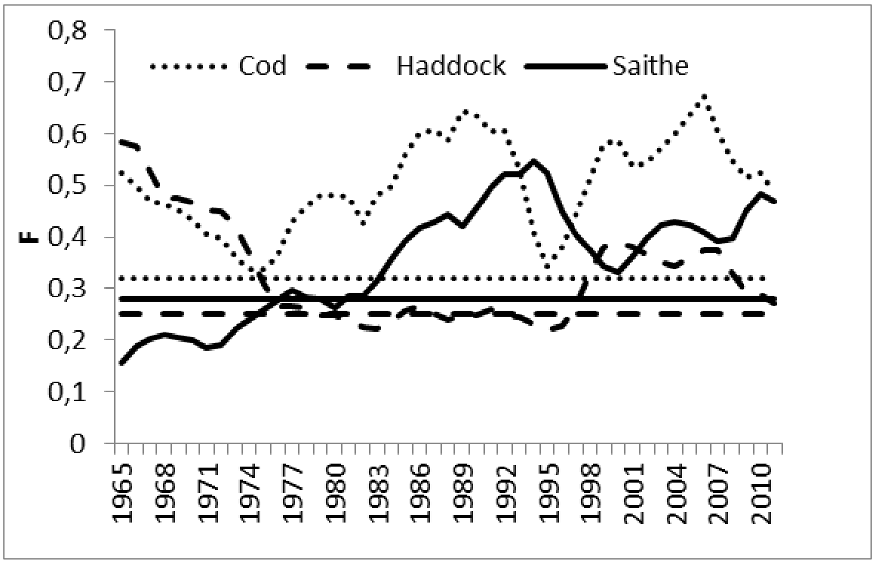
From figure C6.2 we see that the Faroese fleets that are regulated by ITQs (the pelagic and distant water fishery) are much more economically successful than those regulated by the fishing-days system. Figures C6.3 and C6.4 show the biological information on the demersal stocks.

Figure C6.3: Spawning Stock Biomass (SSB), in thousand tonnes for the three species, cod, haddock and saithe, in straight lines are the Bpa (Biomass precautionary approach) for each of these species, five year average



Source: ICES (2013).

Figure C6.4: Fishing mortality (the fishery); straight lines are the FMSY (Fishing mortality – maximum sustainable yield) for each of the species, five year average



Source: ICES (2013).

We see that the stocks are in bad shape at the moment. Biological advice for the demersal fishery in the Faroes is done by ICES together with the Faroese Marine Research Institute, which gives advice to the parliament each year. The final word on how many fishing days are available each year is decided by the Faroese parliament. The decision of the parliament does not usually follow the advice of the biologist (F_{MSY}) (cf. figure C6.4).

C6.3 The fleets

The fishing-days system regulating the fisheries around the Faroe Islands operates with five main groups (Table C6.1). The groups 1 to 3 are the larger vessels, which are the ones included in this study. The groups 1 and 2 are larger single trawlers and pair trawlers both with larger than 400 horsepower engines. Both these groups of trawlers mostly fish saithe. The long liners larger than 110 gross register tonnes (group 3) mainly fish cod and haddock. In addition to these three species, the species with the highest landing values for these fleets are ling (*molva*), tusk (*brosme brosme*), and greater argentine (*argentina silus*). These species are not included in this study due to lack of biological data.

Table C6.1: The groups of vessels in the Faroese fishing-days system. Source: (Fiskidaganevndin, 2012) and (Faroe Islands Fisheries Inspection www.fve.fo)

Group of fishing vessel	Licenses 2010	Landing value million EUR 2010
Group 1: Large single trawlers >400 hp*	10	19.2
Group 2: Pairtrawlers >400 hp	26	46.3
Group 3: Longliners > 110 grt	20	26.6
Group 4: Large coastal vessels >15 grt		
4A: Longliners and jiggers 15–110 grt	16	1.3
4B: Small coastal trawlers < 500 grt	17	5.6
4T: Small trawlers > 55 grt < 500 hp	10	6.7
Group 5: Small coastal vessels < 15 grt (longlining and jigging)		
5A: Full time fishers	74	6.7
5B: Part time fishers	633	4.3
Other vessels (e.g. pelagic and distant water fishing)	22	165.0
Total		281.7

*Group 1 was only introduced into the system in 2010 and included in group 2 in 2011.

Two private fuel companies in the Faroe Islands supply oil to the Faroese fishing fleet. In addition, vessels from the Faroe Islands also buy fuel abroad. The fishing fleet is exempt from all taxes on their fuel, as is all industry in the Faroes. The price of fuel follows the world market price of fuel, and the average price of fuel in 2010 was 0.57 EUR/l, according to the fuel companies.

C6.4 Data

The case study is focused on the three groups 1–3, the pair trawlers, the single trawlers and the long liners. We add the trawlers into one fleet as they have been in the fishing-days system, and because the fleets are similar. Below, we consider the physical and economic data for these two fleets (trawlers and long liners).

Table C6.2: Physical and account data for the demersal fishery in the Faroe Islands. Source: NOTA (2012) and Faroe Islands Fisheries Inspection

	Trawlers	Long liners	Total
Physical data			
Full-time employment	211	221	432
Number of vessels1	30	16	46
Physical assets (million EUR)	18.2	3.4	21.6
No. of days at sea per vessel	241	246	234
Fuel consumption 1,000 liter	24,747	5,957	30,704
Share of national landing value (%)	23.2%	9.4%	32.6%
Main stocks2	Saithe (Cod) (Haddock)	Cod Haddock (Saithe)	
Share of main stocks of value (%)	63.0%	48.9%	58.9%
Account data (EUR Million)			
Turnover1	59.7	24.0	83.7
Fuel costs	14.9	3.6	18.5
Salary	23.0	10.6	33.6
Other operating costs	19.9	8.2	28.1
Capital costs	4.1	1.2	5.3
Depreciation	4.9	1.5	6.7
Profit	-7.1	-1.2	-8.2
Salary per FTE (EUR/year)	108,890	47,857	77,667
Opportunity cost			
Salary (EUR/year)	40,000	40,000	40,000
Capital (%)	6	6	6

[1] From table 1 we see that we do not have full coverage in the first 3 groups, but most of the vessels and turnover are included.

[2] Cod, haddock and saithe are the species where there are biological estimations. Trawlers fish mostly saithe, while long liners fish cod and haddock.

We see that the long liners have the highest number of employees, but the trawlers are by far the largest segment in this study when looking at the turnover and the number of vessels. Both segments had negative profits in 2010, and, as we saw in figure C6.2, this has been the trend for many years.

Next, we consider the biological data to access the maximum economic yields for these species and fleets. We find the SSBmax, which expresses the Spawning Stock Biomass if the fishing follows biological advice (MSY).

Table C6.3: Actual spawning stock biomass, spawning stock which offers the largest renewable catches and fishing mortality levels, tonnes

	Spawning stock biomass		Fishing mortality compared to MSY-level 2010
	Actual 2010	SSB max average 1961–2013	
On the Faroe Plateau:			
Cod	22,211	57,249	Above target
Haddock	18,442	56,001	Above target
Saithe	67,499	94,127	Above target

Note: We have used the average SSB since 1961 as the SSBmax. Source: ICES (2013).

Table C6.3 confirms figures C6.3–C6.4 and we see that all the stocks are in bad shape. The fishing mortality is also above the recommended MSY levels from ICES. This has been the case for a long period, particularly for cod (cf. figures C6.3–C6.4). Using average stocks may not be representative for the SSBmax, and in table C6.10 we try different SSBmax values.

These numbers are used to estimate the production function of the stocks. The production function considered is:

$$Q = aEe^{-bE}$$

where: Q is landings
E is effort
e is the natural number

Using a procedure in Nielsen *et al.* (2011), the parameters a and b are calibrated. The result of this calibration is shown in Table C6.4.

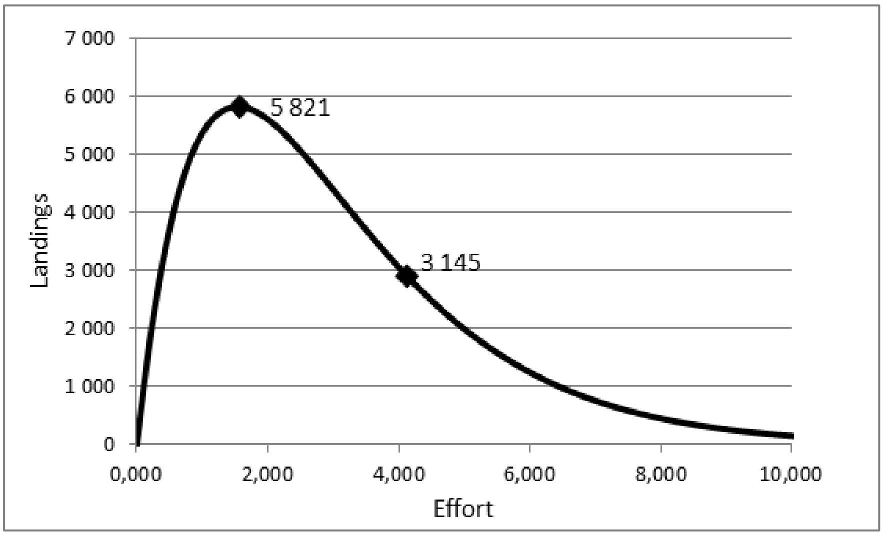
Table C6.4: Calibrated Parameter Values of the Production Function

	Trawlers	Long liners
Parameter a:		
Cod	3,586	10,288
Haddock	1,688	7,800
Saithe	22,073	175
Parameter b:		
Cod	0.35	0.65
Haddock	0.40	0.71
Saithe	0.20	0.38

Note: *a* and *b* are calibrated on the basis of landings with landings in tonnes and 1,000 days at sea.

For cod with long liners this gives for example:

Figure C6.5: Calibrated values for cod with long liners and the function 10,288*E*e$^{-(0.65*E)}$



where 5,821 tonnes are the biologically optimum landings (MSY) and 3,145 tonnes are the current landings. This production function implies that you can reduce effort and still catch more. From fisheries economics theory, we know that the economic optimality in terms of fishing effort is generally lower than the biological optimality (cf. Table C6.8).

C6.4.1 Model

The purpose of the analysis in the project is to identify the socio-economic effects of introducing fuel taxes in fisheries, and to assess the ability of different management systems to adjust to changes in fuel prices. This is done by comparing results from a bio-economic model in different Nordic countries. We use two concepts for evaluating the performance of the fishery. The first concept is resource rent and the second concept is profit. Resource rent is defined as:

> "The net-surplus that, at a given time, remains for the remuneration of capital and labor above the rate that is achieved in other business."

Resource rent is the economic return that is obtained by owning the stock. Thus, resource rent can be understood as the social rent to the resource owner. Under open-access, the resource rent is exhausted and fisheries continue to the point where profit corresponds to that obtained by other activities. In this paper we define resource rent as the sum of marginal and infra-marginal rents. By marginal rent we mean resource rent obtained by the last unit, while infra-marginal rents are rents to the previous units. The reason for this is that the model is based on financial rents. Therefore, separation of marginal and infra-marginal rents is not possible. Profit is the same as resource rent apart from the fact that the actual costs of labor and capital are used in the former. Profit can be understood as the private return to the resource owner.

Resource rent and profits are identified on the basis of account statistics in a given period. Thus, we use a register with account statistics for selected vessels. Total costs are all considered variable, because we want to compare with future situations in the long-run. Therefore, there are no fixed costs in the model in the paper. For comparison, fishing effort, catches and stocks must be in steady-state, and markets for fish must be in equilibrium. Hence, there are no descriptions of adjustments towards equilibrium in the model.

With respect to resource rent, the wages of crew in land-based industry and capital in other businesses are used to calculate costs. Crew in land-based industry and the yield of capital in other businesses are, therefore, considered as measures of opportunity costs. The remuneration of capital in other businesses corresponds to the interest on government bonds. We assume perfect competition in the capital market. Invested capital is measured by excluding the value of fishing rights, because value from selling fishing rights can be considered as a transfer. Selling and buying fishing rights only imply transfers of money between the agents. No real value arises for society in connection with transfers of fishing rights.

In this paper we consider four alternatives concerning the cost function:

1. The baseline case without fuel and energy taxes.
2. The case where fishermen pay the existent CO_2 and energy taxes in the country.
3. The case where the existent CO_2 emission permit price of EUR 34.01 EUR/1,000 l is paid for coal, oil, natural gas and electricity in the EU (Stern (2006)).
4. The case where fishermen pay the long-run equilibrium permit price of EUR 159.02 /1,000 l in the EU according to Stern (2006).

The four alternatives correspond to different assumptions on fuel costs. In the first case no fuel and energy taxes are paid. This corresponds to the existing tax structure in the Nordic countries. The second case arises when the existing fuel and energy tax in a country is paid. Here the fishing sector pays exactly the same taxes as other industries, which in the Faroese case is the same as the baseline case. The existing CO_2 permit price in the EU is paid in the third case. This is the case where the national fishing sector is included in the EU permit market. In the last case the long-run equilibrium (year 2100) permit price is paid based on the forecasted price in Stern (2006). Here the fishing industry is also included in the EU permit market and the long-run value of permits is the relevant cost to include.

These four alternatives are evaluated using both profit and resource rent. The resource rent and profit are evaluated in three steps. First, the revenue is identified using biological information. Second, costs are arrived at. Last, the maximum resource rent and profit are calculated. Effort adjustments are identified, both totally and for each fleet segment. In addition, CO_2 consumption, fuel consumption, and other data are identified for each fleet segment.

C6.5 Results

The result section starts with a presentation of the current situation and profits and resource rent with fuel taxes and without any maximization. Next the estimations of the parameters in the production functions are described and the results from the model optimization for each of the scenarios are presented.

The scenarios that we operate with are the following:

0. Baseline – current profit and resource rent (=2010).
1. Maximization of profit and resource rent in current situation.
2. Maximization of profit and resource rent with current energy and CO_2 tax structure imposed on fisheries.
3. Maximization of profit and resource rent with current CO_2 quota prices imposed on fisheries.
4. Maximization of profit and resource rent with predicted CO_2 quota prices in 2100 (according to Stern) imposed on fisheries.

C6.5.1 The current situation

Introducing fuel taxes like the EU CO_2 taxes and the Stern tax in the current situation, and assuming that fishers do not profit maximize or change their choice of inputs or outputs in any way, would result in a decrease of an already negative total profit for the segments in the study. The profits and resource rents for the two fleets, where the fuel taxes are only included in the costs, are calculated in Table C6.5:

Table C6.5: Introducing fuel taxes in the current situation

	Current profit				Current resource rent			
	No fuel tax	National fuel taxes imposed	EU CO2 tax imposed	Stern tax imposed	No fuel tax	National fuel taxes imposed	EU CO2 tax imposed	Stern tax imposed
Trawlers	-7.1	-7.1	-7.1	-7.4	10.4	10.4	10.4	10.1
Long liners	-1.2	-1.2	-1.2	-1.2	1.5	1.5	1.5	1.5
Total	-8.2	-8.2	-8.2	-8.6	12.0	12.0	12.0	11.6

Both profits and the resource rent show only minor effects of introducing fuel taxes. The reason for the difference between profit calculation and resource rent calculation is that the wages used when calculating profits are higher than the opportunity wages used when calculating resource rent.

These are the short-run effects of introducing fuel taxes. In table C6.6 we look at introducing fuel taxes in an optimal fishery.

Table C6.6: Different scenarios for fuel taxes and effects from maximizing *profits*

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Maximum profit (EUR Million)					
Trawlers	-7.1	29.1	29.1	29.0	28.6
Long liners	-1.2	21.3	21.3	21.3	21.2
Total	-8.2	50.4	50.4	50.3	49.8
Number of vessels					
Trawlers	30	11	11	11	11
Long liners	16	5	5	5	5
Total	46	16	16	16	16
Number of days					
Trawlers	7,227	2,626	2,626	2,618	2,589
Long liners	3,928	1,263	1,263	1,262	1,259
Total	11,155	3,889	3,889	3,880	3,848
Effort change (%)					
Trawlers	.	-64	-64	-64	-64
Long liners	.	-68	-68	-68	-68
Total	.	-65	-65	-65	-66
Fuel consumption (1,000 l)					
Trawlers	24,747	6,437	6,437	6,398	6,256
Long liners	5,957	1,318	1,318	1,315	1,306
Total	30,704	7,755	7,755	7,713	7,562
C02 consumption (tonnes)					
Trawlers	61,868	16,093	16,093	15,995	15,640
Long liners	14,893	3,295	3,295	3,288	3,265
Total	76,760	19,388	19,388	19,283	18,905

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Catch (tonnes)					
Trawlers	72,713	51,350	51,350	51,266	50,955
Long liners	12,098	12,097	12,097	12,094	12,083
Total	84,811	63,447	63,447	63,360	63,038
Employed (FTE)					
Trawlers	211	55	55	55	54
Long liners	221	49	49	49	49
Total	432	104	104	104	103
Catch (kg) pr liter fuel					
Trawlers	2.9	6.1	6.1	6.1	6.3
Long liners	2.0	7.5	7.5	7.6	7.6
Total	2.8	6.3	6.3	6.4	6.5
Revenue (EUR) pr liter fuel					
Trawlers	1.5	4.3	4.3	4.3	4.4
Long liners	2.0	12.0	12.0	12.0	12.1
Total	1.6	5.7	5.7	5.7	5.7

Several interesting results emerge from this table. We see that the profits are negative in the current situation but will become positive if the optimal fleet is used. If the fishery is optimized we see that the profit can go from EUR-8.2 to EUR 50.4 million (DKK -61 million to DKK 376 million).

Table C6.7: Different scenarios for fuel taxes and effects from maximizing *resource rents*

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Maximum resource rent (mEUR)					
Trawlers	10.4	34.2	34.2	34.1	33.6
Long liners	1.5	21.9	21.9	21.9	21.8
Total	12.0	56.1	56.1	55.9	55.4
Number of vessels					
Trawlers	30	13	13	13	13
Long liners	16	5	5	5	5
Total	46	18	18	18	18
Number of days					
Trawlers	7,227	3,093	3,093	3,083	3,047
Long liners	3,928	1,305	1,305	1,304	1,259
Total	11,155	4,398	4,398	4,387	4,347
Effort change (%)					
Trawlers	.	-57	-57	-57	-58
Long liners	.	-67	-67	-67	-67
Total	.	-61	-61	-61	-61
Fuel consumption (1,000 l)					
Trawlers	24,747	8,005	8,005	7,950	7,750
Long liners	5,957	1,376	1,376	1,373	1,362
Total	30,704	9,381	9,381	9,322	9,113
C02 consumption (tonnes)					
Trawlers	61,868	20,013	20,013	19,875	19,375
Long liners	14,893	3,440	3,440	3,433	3,405
Total	76,760	23,453	23,453	23,350	22,783

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Catch (tonnes)					
Trawlers	72,713	55,910	55,910	55,822	55,500
Long liners	12,098	12,215	12,215	12,212	12,201
Total	84,811	68,124	68,124	68,034	67,701
Employed (FTE)					
Trawlers	211	68	68	68	67
Long liners	221	51	51	51	51
Total	432	119	119	119	118
Catch (kg) pr liter fuel					
Trawlers	2.9	5.3	5.3	5.3	5.4
Long liners	2.0	7.2	7.2	7.2	7.3
Total	2.8	5.5	5.5	5.6	5.7
Revenue (EUR) pr liter fuel					
Trawlers	1.5	5.1	5.1	5.2	5.3
Long liners	2.0	8.9	8.9	8.9	9.0
Total	1.6	5.7	5.7	5.7	5.8

We see that the resource rent is increased dramatically so that it is positive today with EUR 11 million and it is increased optimally to EUR 56.1 million (DKK 89 million is increased to DKK 413 million). The four scenarios are not that different regarding the optimal profits and resource rent. So this points to the conclusion that fuel taxes do not matter. The fuel consumption and CO2 emissions are much lower in all scenarios.

The number of vessels is reduced dramatically for both segments. If we want to maximize profits, there should be 11 instead of 30 trawlers, and there should be 5 instead of 16 long liners, according to this calculation. If we instead maximize resource rent, the numbers should be 13 trawlers and 5 long liners. The reason for this difference in trawlers lies in the different calculations in the two cases, and e.g. alternative wage payments are lower than actual wage payments, and therefore there can be more vessels in optimum when maximizing the resource rent.

In these calculations we have not considered alternative ways of getting the fish from the ocean; by other kinds of vessels for example. This calculation is made for the long run, and the fact that the stocks are in bad shape right now is not considered. The employment situation for those employed on vessels that become redundant is not considered in the calculations. But we can see that the number of employed goes from 432 to 104 i.e. 328 fishermen fewer, if we maximize profits, but the gains are DKK 438 million, so it is DKK 1.3 million per fisherman each year. Finally, other parts of the economy are not considered, e.g. fish factories.

In tables C6.6 and C6.7 we saw that the profit was higher in optimum while the total catch was lower. In table C6.8 we consider the catches of different species when maximizing profits:

Table C6.8: Catches in optimum profit scenarios. Total landings in tonnes, all segments, different species

	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO2 quota price	4. Stern quota price
Cod					
Trawlers	2.066	3.756	3.756	3.755	3.752
Long liners	3.145	5.718	5.718	5.717	5.714
Total cod	5.211	9.474	9.474	9.472	9.465
Haddock					
Trawlers	677	1.551	1.551	1.551	1.551
Long liners	1.884	4.019	4.019	4.018	4.017
Total haddock	2.561	5.569	5.569	5.569	5.568
Saithe					
Trawlers	37.592	34.280	34.280	34.232	34.052
Long liners	155	137	137	137	137
Total saithe	37.747	34.417	34.417	34.368	34.188
Other species					
Trawlers	32.378	11.764	11.764	11.728	11.600
Long liners	6.914	2.224	2.224	2.222	2.216
Total other species	39.292	13.987	13.987	13.951	13.816
TOTAL	84.811	63.447	63.447	63.360	63.038

From table C6.8 we see that there are two species, cod and haddock, where the catches go up for both fleets in optimum. This can be done as the stocks currently are at historically low levels. Catches of the other species, saithe, go down for both fleets. The other species group is reduced by the same percentage as the total effort is reduced, so the catch also goes down.

C6.5.2 Sensitivity analysis

In order to check how sensitive our results are to changes in the parameters of the production functions, we run the profit maximization scenario (scenario 1) with three different changes to the parameters. The first analysis (K1) increases the a-parameters by 25% and keeps the b-parameters at their calibrated values. The second analysis (K2) decreases the b-parameter by 25%, and the third analysis (K3) decreases the b-parameter by the same amount. The a-parameter is kept at its calibrated value in the second and third analyses.

Table C6.9 shows the effects in scenario 1 (profit maximization) of the sensitivity analysis of profit, the number of vessels, fuel consumption and effort changes. Decreasing the a- parameter (K2) in all stocks for all segments results in a lower total profit, which is expected, since parameter a is an indication of the volume of landings. All segments get a lower profit and the ranking between segments is unchanged. Changing the b-parameter also preserves the ranking between segments. An increase in the b-parameter means that a unit effort gives a smaller amount of fish, and thus profit gets smaller compared to the original values. In contrast, a decrease in the b-parameter means that each unit of effort gives a larger amount of fish. This is the reason for profit being larger in sensitivity analysis K3 than in sensitivity analysis K2.

Table 9: Sensitivity analysis: Effects on profit, number of vessels, fuel consumption and effort.

	Originally calibrated values of a and b	K1: parameter a decreasing by 25%	K2: parameter b increasing by 25%	K3: parameter b decreasing by 25%
Profit, EUR Million				
Trawlers	29.1	19.7	24.3	36.6
Long liners	21.3	15.5	17.3	27.6
Total	50.4	35.2	41.7	64.3
Number of vessels				
Trawlers	11	10	9	13
Long liners	5	5	4	5
Total	16	15	13	18
Change in effort				
Trawlers	-64%	-68%	-70%	-54%
Long liners	-68%	-69%	-69%	-58%
Total	-65%	-68%	-68%	-56%

We see that decreasing the a-parameter results in fewer vessels but lower profits. This is also what happens when increasing the b-parameter. And we see that decreasing the b-parameter results in more vessels since this means that fewer fish are caught per unit of effort. Finally, if we decrease the a-parameter, this results in less fuel consumption and less effort in the fishery. This also happens when increasing the b-parameter.

These changes in a and b can be illustrated by looking at figure C6.3 again:

Figure C6.4: Calibrated values for cod with long liners and the function 10,288*E*e$^{-(0.65*E)}$

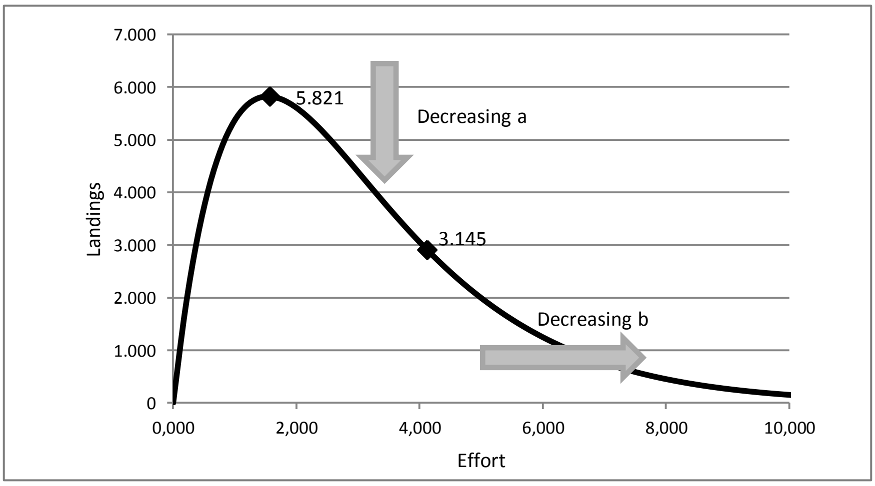


Figure C6.4 illustrates the point that increasing the parameter a moves the graph downwards, while decreasing b moves the graph outwards. If we increase b the graph moves inwards. So the effects that we saw above can be seen in figure 4, e.g. when a was decreased by 25%, it led to lower profits due to lower catches. When b was decreased, it also led to lower profits than the original maximization. Finally, when b was increased, this led to higher profits.

Another way to consider the a and b parameters is to look at the biological data again. In table C6.3 above the average biomass was used to calibrate the production function. This value (SSBmax) is not estimated by ICES, but one biomass that is estimated by ICES is the B_{pa} where pa stands for precautionary approach, and this value is used in table C6.10.

What we really want is the estimated value for the biomass when using MSY; this is called the $B_{MSY,}$ which is quite hard to estimate and is not done by ICES. But Faroese biologists from the Faroese Marine Research Institute (Steingrund 2010) estimate that the SSBmax would be much higher than the average for the last 50 years, since we have overfished the stocks for so long. In table 10 we see the results if these estimated values of SSBmax are used.

Table C6.10: Sensitivity analysis with different levels of SSBmax for the species.

	Average stock (current)[1]	B_{pa}[2]	Faroese biologists[3]
Profit, EUR Million			
Trawlers	29.1	16.7	39.0
Long liners	21.3	11.6	35.0
Total	50.4	28.2	74.0
Number of vessels			
Trawlers	11	11	10
Long liners	5	6	4
Total	16	17	14
Catch			
Trawlers	51,350	48,713	55,926
Long liners	12,097	8,818	17,681
Total	63,447	57,531	73,643
Change in effort			
Trawlers	-64%	-62%	-68%
Long liners	-68%	-63%	-73%
Total	-65%	-62%	-70%

1. SSBmax cod 57.249 t, SSBmax haddock 56.001 t, SSBmax saithe 94.127 t.
2. SSBmax cod 40.000 t, SSBmax haddock 35.000 t, SSBmax saithe 60.000 t.
3. SSBmax cod 80.000 t, SSBmax haddock 80.000 t, SSBmax saithe 100.000 t.

From table C6.10 we see that the effects on the profits are very high, while the effects on the number of vessels and effort are not so high from changing SSBmax. If we decrease the SSBmax, the maximum profits are lower with more vessels and lower catches. If, on the other hand, we increase SSBmax, the profits increase while the number of vessels is lower and the catch is higher. If we considered the resource rent instead, it would be higher than the profits (EUR 78.6 million in the last case), and the catch and number of vessels would also be higher.

C6.6 Conclusions

In this note we consider the effect of various fuel policies on the performance of fisheries. We consider five scenarios:

0. The present situation with exemption of fuel and energy taxes.
1. Optimization in the present situation.
2. National tax policy imposed on fisheries.
3. Current EU CO2 quota prices used in fisheries.
4. Long-run EU CO2 quota price according to Stern (2006).

The difference between the present situation and the four other scenarios is large, and we go from a current deficit of EUR-8.2 million to a profit of EUR 50.4 million, or from a current resource rent of EUR 12 million to a resource rent of EUR 56.1 million in optimum. Therefore, there is a considerable gain in moving to optimal management. However, the differences among the four scenarios are small. This conclusion holds irrespective of whether the effect is measured in profit, resource rent, number of vessels, effort, CO_2 consumption or fuel consumption. Thus, there is very little to be gained when choosing among various fuel policies. The policy implication of this is that the most efficient policy is not a fuel policy but simply a movement to optimal management. In the Faroese case this could be to introduce individual transferable quotas for the demersal fleet, so that the fleet will adapt to a more economically optimal state (cf. figure C6.2).

References

Birk-Mortensen, J (2009), The EU CO_2-quota market – facts and implications. Information, 23/1 2009.

Nordhaus W (2007), Critical Assumptions in the Stern Review on Climate Change. Science 317:201–202.

Nielsen, M., O. Flaaten and S. Waldo (2012), Management of and Economic Returns from Selected Fisheries in the Nordic Countries, Marine Resource Economics, 27 (1), 64–88, March 2012.

OECD (2011), "OECD Territorial Reviews: NORA Region 2011: The Faroe Islands, Greenland, Iceland and Coastal Norway". OECD Publishing.

Fiskidaganevndin (2013) Tilmæli frá Fiskidaganevndini til landsstýrismannin í fiskivinnumálum.

ICES (2013) Report on the North Western Working group, ICES.

NOTA 2012 "Report on accounts of Faroese fishing vessels", NOTA.

Steingrund, P. (2009), The near-collapse of the Faroe Plateau cod (Gadus morhua L.) stock in the 1990s: The effect of food availability on spatial distribution, recruitment, natural production and fishery, Dr. Philos thesis, University of Bergen.

Stern, N. (2006), Review on the Economics of climate Change, Cambridge University Press.

C7. Finland

Fredrik Salenius, University of Helsinki

C7.1 Introduction

One outcome of the G-20 summit in Pittsburgh in 2009 was an appeal for global focus on fossil fuel subsidies as an effort to mitigate climate change. The G-20 leaders expressed a wish that inefficient fuel subsidies be phased out and rationalized over the medium term. Reducing support to fuel use can generate both environmental and economic benefits. Because fuel tax concessions are often less transparent than other support measures, they might easily be neglected when considering policy reforms (Martini 2012).

In this project we ask what the consequences for different Nordic fisheries would be if a tax is imposed on fuel, i.e. if the fuel subsidy to fisheries is removed. Environmental taxes are designed to take into account the negative externalities of certain actions (for example the use of motor fuel), so that the cost of the environmental damage is incorporated into market prices, and therefore affects the decisions of the consumers. The price elasticity of fuel is in fact quite high in the long run, which means that fuel taxes can be a powerful instrument of environmental policy. Therefore, a discussion of an extension of the use of fuel tax policies to other sectors, notably industry, is called for (Sterner 2007). The fishing sector is one industry where taxes in general have not been commonly used as a management instrument. On the contrary, fuel use in the fishing sector is often supported financially in different ways (Martini 2012). The FAO (2009) has stated that fisheries make a small but still significant contribution to greenhouse gas emissions.

The Finnish case studies the coastal salmon fishery in the Gulf of Bothnia. Management of salmon should be based on the assessment of individual river stocks, and the specific target of our study is the River Tornionjoki (Torne River) salmon stock. River Tornionjoki produces one third of the wild salmon in the Baltic Sea, which translates to a salmon catch of several hundred thousand kilograms per year for the fishermen in the Baltic Sea region. Although the salmon fishery is not the most significant in terms of e.g. landing weight or value, it is one the most controversial fisheries in the region. The primary reason for this is that all Baltic salmon stocks are endangered. Highly differing views among stakeholders (commercial fishermen, recreational fishermen, policy makers, environmental organizations) on issues concerning exploitation of the fishery are not uncommon.

We study the effect of fuel taxation on the fishery by comparing four policy scenarios with the current situation. The current situation represents the factual economic performance of the fishery today. In the four tax scenarios we apply optimal management and maximize the net present value (NPV) of the fishery assuming different tax policies, as indicated in Table C7.1. We will also look at the effect of taxes under current management. We are mainly interested in effects on fishing effort and NPV of the fishery, but fuel consumption and carbon dioxide (CO_2) emissions are also considered. Moreover, the sustainability of the salmon fishery is discussed.

This paper is laid out as follows. Next, fuel taxation practices in Finland and the fuel tax exemptions for Finnish fisheries are discussed. Section C7.3 briefly presents the salmon fishery in the Gulf of Bothnia. Section C7.4 gathers relevant data on fuel taxes and the salmon fishery. The model used for the maximization calculations is presented in section C7.5. The results from the model runs (section C7.6) and a discussion of these (section C7.7) conclude the paper.

Table C7.1. Fuel tax scenarios

Scenario	Definition
0. Current situation	Statistics
1. Benchmark	Fuel exempt from taxes
2. National taxes	Finnish energy content tax and CO_2 tax
3. EU emission allowances	EU CO_2 quota price in 2009
4. Stern	CO_2 quota price in 2100 (Stern 2006)

C7.2 Fuel taxation in Finland

As a member of the European Union (EU), Finland is bound by the Energy Taxation Directive of 2004.[16] This directive defines the energy products and lays down the minimum fuel taxation levels in the Member States. We are interested here in the liquid fuels used in fishing vessels: motor gasoline, diesel oil and fuel oil (Martini 2012).

---

[16] In April 2011 the European Commission presented its proposal for a renewal of the rules on taxation of energy products in the European Union. The new way of taxation takes into account both CO_2 emissions and energy content of energy products. This revision supports the Commission's ambition to promote energy efficiency and consumption of more environmentally friendly products (European Commission 2012).

Excise duty is collected according to the Act on Excise Duty on Liquid Fuels of 1994. As of January 2011, the taxation of fuel is carried out through taxation of fuel components. These components are energy content tax and CO_2 tax, which consider the fuel's energy content and CO_2 emissions respectively (Ministry of Finance 2012; National Board of Customs 2012a). In the case of motor gasoline and diesel oil, as well as their bio-based substitutes, the CO_2 tax is calculated based on the CO_2 equivalent emissions that arise during the fuel's life cycle. Thus, the tax on these fuels is graded according to the fuel's environmental impact. This is the ruling as of 1 June 2012 (Finlex 1472/1994; Ministry of Finance 2012).

Table C7.2 shows the excise duty rates as cents per liter for fuels used by fishing vessels. There is also a strategic stockpile fee that is imposed on liquid fuels and other energy products. This fee is meant to cover the government's expenses caused by emergency stockpiling and other measures carried out to secure energy supplies (National Board of Customs 2012a).

Table C7.2. Excise duty rates on fuels used by fishing vessels, as of 1 January 2013.

Product	Energy content tax	Carbon dioxide tax	Strategic stockpile fee	Total
Motor gasoline c/l	50.36	14.00	0.68	65.04
Diesel oil c/l	30.70	15.90	0.35	46.95
Light fuel oil c/l	9.30	9.34	0.35	18.99

C7.2.1 Fuel tax exemptions in the Finnish fishing sector

The European Union's Energy Taxation Directive lays down, apart from minimum tax rates, the rules for tax exemptions. The Directive states that commercial fishing activities can be exempted from fuel taxes in Community waters. In Finland, this is stated in Article 9 of the Act on Excise Duty on Liquid Fuels. *The tax exemption covers the full value of the excise duty*. Only fishing vessels used for professional fishing are exempt from fuel taxes. In the Fishing Act, a professional fisher is defined as a person who earns at least 30% of regular total income from fishing and processing of the catch. Additionally, a professional fisher has to be included in the register of professional fishermen. The vessels used in professional fishing also need to be included in the register for fishing vessels (Ministry of Agriculture and Forestry 2005; National Board of Customs 2012b).

Fuel tax concessions represent substantial amounts of money in many countries. Sumaila *et al.* (2006) estimate that fuel subsidies account for about 25% of total fisheries subsidies. The estimated total value of fuel tax concessions in OECD countries was EUR 1.5 billion in

2008. The total amount of fuel consumed amounted to 9.3 billion liters, which also included non-subsidized fuel (Martini 2012). In Finland, the fuel tax exemptions for professional fishers amounted to EUR 310,000 in 2008 and EUR 260,000 in 2009 (OECD 2012). Table C7.3 shows the values of tax concessions and volumes of fuel consumed in the Finnish fishing sector in 2008.

Table C7.3. Fuel tax concessions for Finnish fisheries, 2008 (Martini 2012)

Fuel type	Tax concession value, EUR	Fuel consumed, l
Motor gasoline	234,600	374,400
Diesel oil	5,700	15,800
Fuel oil	72,400	836,500

C7.3 The Baltic salmon fishery

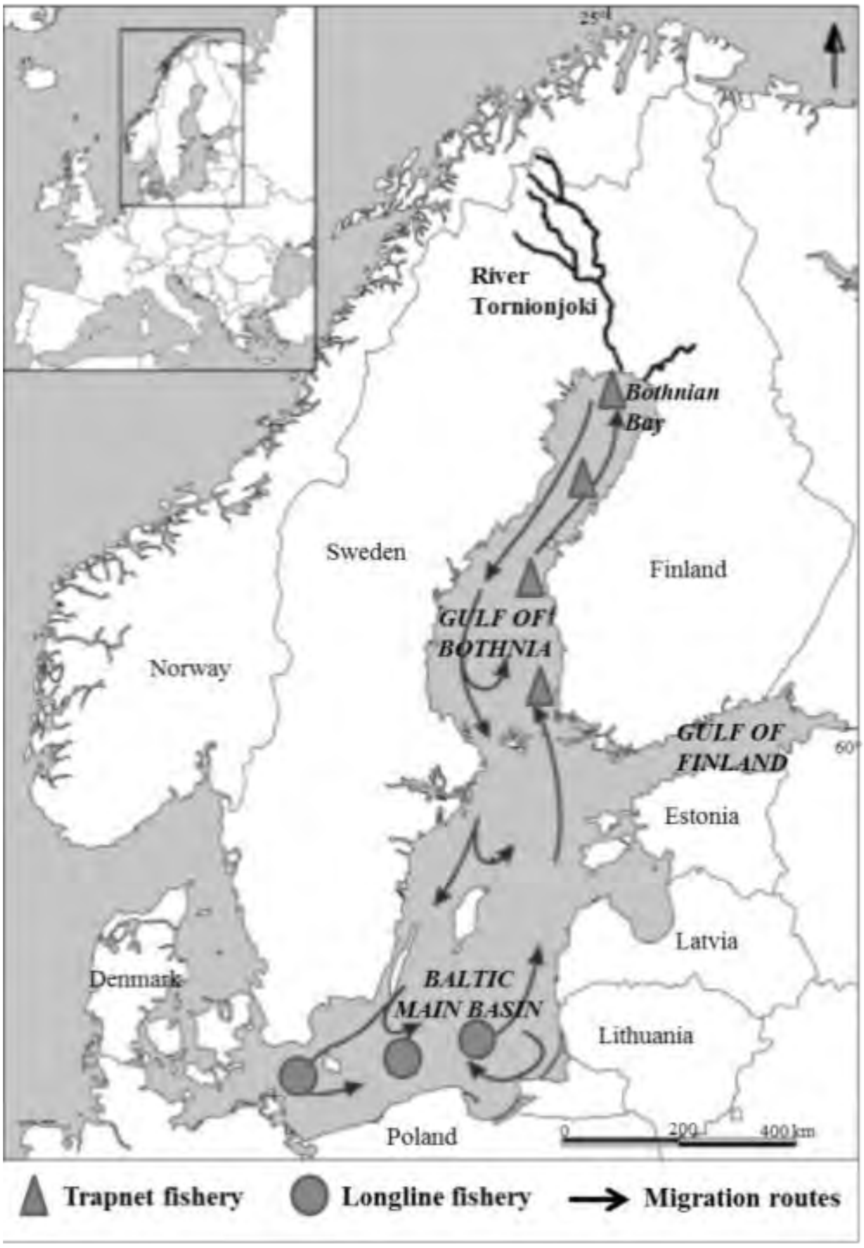
In Finland, the majority of the commercial salmon catch is taken by the coastal trapnet fishery. In fact, today this is the only type of commercial salmon fishing allowed, since offshore longlining is prohibited as of 2013. Denmark and Poland still fish with longlines in the southern Baltic Sea. In the modeling in this study, a fixed proportion of the stock is assumed to be harvested by the longline fishery. The use of driftnets was banned by the EU in 2008. Salmon from the northern Baltic rivers, such as River Tornionjoki, are caught in the Gulf of Bothnia. The coastal fishery underwent technological improvements in the late 20th century, e.g. seal safe trapnets were developed. The major part of the catch is taken with salmon trapnets, whitefish trapnets and push-up trapnets. The push-up trap is a fairly new type of trapnet, which protects the catch from seals. The trapnet fishery takes place in June and July, when the mature salmon migrate to their natal rivers to spawn. In recent years roughly 150 fishermen and 400 trapnets have been engaged in the Gulf of Bothnia salmon fishery. The fishing effort has not changed notably in recent years. In 2012, the coastal trapnet fishery accounted for 83% of the total commercial salmon catch in Finland.

The Baltic salmon fishery is managed through a *total allowable catch* (TAC), which is allocated by the European Commission to the Baltic Sea countries. For 2013, the Commission proposed a TAC of 108 000 salmon for the Gulf of Bothnia and the Main Basin. Finland's share of the TAC was 28,000 salmon. There are national *time restrictions* on the coastal fishery in order to save a proportion of the spawning migrators from the coastal harvest. Finland has set time restrictions on the salmon fishery in its economic zone in the Gulf of Bothnia. The *minimum landing size* of Baltic salmon is 60 cm. An exception is the Bothnian Bay fishery, where the minimum size has been decreased to 50 cm. However, size regulation does not play an important role in the coastal fishery, because the majority of spawners are 60–90 cm long.

Disagreement among stakeholders on the size of the annual TAC is a recurring theme surrounding the Baltic salmon fishery. In recent years the policy makers have agreed on much larger total catch shares than advised by the International Council for the Exploration of the Sea (ICES.) The cautious recommendations by ICES are largely explained by the extensive unaccounted salmon fishing that is assumed to occur. Mis- and unreported catches were estimated to be about 30% of the total salmon catch in 2011 (ICES 2012).

According to a survey done by ICES in 2011, River Tornionjoki and several other rivers flowing into the Bothnian Bay have stocks approximately at the MSY-level. This means that the river's smolt production is at least 75% of the potential smolt production capacity. However, the fishing mortality for these stocks should not be allowed to increase (ICES 2011).

Figure C7.1. The migration routes and main fisheries of northern Baltic salmon stocks



C7.4 Data

Here, we summarize the relevant data on fuel costs and the salmon fishery. The CO_2 tax in the EU and Stern scenario are the same for all countries and case studies, whereas the national tax varies between cases. Data used in the modeling is from 2009 and 2010. In 2009, before the energy tax reform, the fuel tax in Finland consisted of basic duty and additional duty as well as a stockpile fee (Ministry of Finance 2009). However, the basic and additional duty here can be thought of in terms of an energy and CO_2 tax.

Because the Finnish study assumes the use of petrol (motor gasoline),[17] and not diesel as in the other cases, a different figure for CO_2 emissions on combustion is needed. Here 2.33 kg CO_2 per liter of petrol is used (Biomass Energy Centre). When multiplying this with the CO_2 costs, we obtain the cost of CO_2 per 1,000 liters of petrol (see Table C7.4).

The figures for EUR per tonne CO_2 are the ones established for the project. The EU tax is based on the price for EU emission allowances in the European Energy Exchange. In this scenario the fishery is assumed to operate within the European Union Emissions Trading System (EU ETS), where it buys CO_2 quotas. EUR 13.03 per tonne CO_2 was the average quota price in 2009.

The fuel tax in the Stern scenario is based on the estimated cost of global warming presented in the Stern Review on the Economics of Climate Change. $85 was the price per tonne CO_2 presented by Stern (2006), which implies the social cost of CO_2 today if we remain on the business-as-usual trajectory. Using the yearly average exchange rate in 2009, we obtain EUR 60.93 per tonne CO_2.

In the calculations, the national tax exemption is based on the excise duty in 2009, which amounted to 62.70 cents per liter of petrol (Ministry of Finance 2009). The CO_2 taxes for the EU and Stern scenarios amount to 3.036 cents and 14.196 cents per liter of petrol, respectively. The price for petrol (98 octane) used here is EUR 1.322 per liter, which is representative for the consumer price in 2009 (Finnish Petroleum Federation). Thus, this is the price paid by the fishermen in the national tax scenario.

---

[17] This is a reasonable assumption, since a considerable number of the fishing vessels that operate in the coastal fishery are small vessels (<10m) that mainly run on petrol.

Table C7.4. CO_2 and petrol costs in 2009

Scenario	EUR/tonne CO_2	EUR/m^3 fuel
Finnish fuel tax		627.0
Energy tax		572.4
CO_2 tax		47.8
Stockpile fee		6.8
EU CO_2 quota price 2009	13.03	30.36
Optimal CO_2 quota price 2100	60.93	141.96

Table C7.5 presents physical and economic data on the salmon fishery in the Gulf of Bothnia. The salmon fishery does not constitute a fleet segment of its own, wherefore data on expenditures is not readily available. Operating costs and fuel consumption here have been estimated based on interviews with fishermen (more on this in the next section). The fishery's net profit, or resource rent, is the difference between landings income and total costs. As can be seen, the salmon fishery is currently unprofitable.

Table C7.5. Physical and economic data for the Finnish salmon trapnet fishery in the Gulf of Bothnia, 2010

Indicator	Value
Fleet	
Number of fishers/vessels	149
Number of gear	448
Effort (trapnet days)	17,342
Days at sea	39
Harvest (1,000 kg)	142
Harvest (nr. of fish)	23,028
Economic data (EUR 1,000)	
Income	
Landings income	609
Costs	825
Fuel	63 (7.6%)
Labor	186 (22.6%)
Other variable costs	576 (69.8%)
Net profit	-216[1]
Fuel	
Cubic meters (m^3)	240
CO_2 emissions (tonnes)	559
Kg catch/liter	0.59
Landings value (EUR /liter)	2.54

1. Excluding non-fuel subsidies.

The commercial salmon fishery belongs to the fleet segment: vessels <10m using passive gear. This segment has been unprofitable, with poor economic results, most probably caused by a high cost structure compared to fish market prices. Although a direct parallel cannot be drawn between the whole segment and the salmon fishery, a relation between the two is discernible. In 2010, this segment reported losses of about EUR 2.7 million. The segment consists of approximately 1500 vessels, and had a landings value of EUR 8 million in 2010 (STECF 2012). Considering that in this study we do not take into account the trapnet fishery in the Gulf of Finland, it seems that the salmon fishery makes up for about one tenth of this fleet segment. As can be seen from Table C7.5, the Gulf of Bothnia fishery accounts for 150 vessels, EUR 609,000 in landings value and EUR 216,000 in losses. This confirms that the cost estimations used in the profitability calculations here are feasible.

C7.5 Bioeconomic model

A bioeconomic model is used to evaluate the economic performance of the salmon fishery under different tax policies. These results are compared to i) optimization results where no taxes are present, ii) the current situation without taxes and iii) the current situation if taxes are introduced.

C7.5.1 Population model

The biological part of the model consists of an age-structured population model, which considers the life cycle of salmon and allows an analysis of economically significant age groups. The population model forms the constraint in the economic optimization. The model is calibrated with data for the River Tornionjoki salmon stock. The stock data is from the 2010 report by ICES' Assessment Working Group on Baltic Salmon and Trout (WGBAST).

C7.5.2 Economic model

Table C7.6 presents the economic parameters utilized in the model. Fishing effort is measured in geardays, which is calculated by multiplying the number of fishing days by the number of gear (trapnets). The cost parameter is defined as EUR per trapnet day. Four different unit costs are utilized in the model run, one for each tax scenario: Benchmark, National, EU and Stern. The fishing costs have been estimated by interviewing Finnish fishermen who participate in the Gulf of Bothnia salmon fishery. The variable costs considered are gear price, gear maintenance, vessel maintenance and labor and fuel costs. Taking into account these expenses, we have calculated the cost of fishing with one trapnet for one day.

Previous existing data on trapnet fishing costs is scarce. Kulmala *et al.* (2008a) estimated unit costs based on interviews with fishermen, and obtained EUR 24.1/gearday. This cost is substantially lower than the EUR 47.6/gearday that is used in the calculations here. The primary reason for this large difference is that our cost estimations are based on the use of seal-safe gear: push-up trapnets or modified traditional trapnets. The gear price is by far the largest share of the total unit cost.[18] Holma *et al*. (2012) have used the cost EUR 43.8/gearday for seal-safe gear.

In the no-tax scenario (Benchmark), fuel is only the fourth largest cost share, after gear price, labor and gear maintenance. This same cost structure prevails in the EU and Stern tax scenarios. In the national tax scenario, however, fuel cost is the third largest cost share, exceeding the cost of gear maintenance. Total fishing cost is obtained by multiplying the unit cost of fishing with the total number of geardays.

Table C76. Economic parameters

Parameter	Symbol	Value
a) Mean cost per unit of effort[1] (EUR /gearday)	c_B	47.55
	c_N	50.83
	c_E	47.71
	c_S	48.29
Age-specific catch price[2] (EUR /fish)	p_a	10.6; 26.4; 41.2; 41.6; 48.5
Proportion of River Tornionjoki salmon	j	0.3
Discount rate	r	0.05
Gutted fish proportion[3]	g	0.75

1. Subindexes B, N, E and S denote the different scenarios.
2. The catch price is for gutted fish.
3. This parameter describes the proportion of fish that is left after gutting.

The control variable in our optimization problem is fishing effort E. We are seeking the level of effort that will maximize the discounted net benefits from the salmon stock over time. The timespan used in the model run is 50 years. The optimization and numerical analysis is done with Matlab, using the fmincon toolbox. We apply open-loop optimization, where the control variable is fixed in the first period. The state variable (stock size) and harvest are constraints and are defined dynamically through time.

The revenue of the trapnet fishery is defined as $p_a h(t)_a$, i.e. catch price times harvest. Cost is defined as scenario-specific cost times fishing effort: $c_{sc}E$. Subtracting costs from revenues and taking into account the discount rate allows us to calculate the net present value of the salmon fishery where scenario-specific cost $c_{sc} = c_B, c_N, c_E, c_S$. g is the parameter for gutted fish, j is the Tornionjoki parameter and $(1+r)^{t-1}$ is the discount factor.

---

[18] The price for a push-up trapnet is around EUR 15 000.

$$P(t) = \sum_{t=1}^{50} [p_a h(t)_a g - (c_{sc}\, Ej)]/(1+r)^{t-1} ,$$

C7.6 Results

The study results are presented in the tables below. First, Table C7.7 shows the effects on profitability of introducing fuel tax policies in the current situation. The added cost is obtained by multiplying the EUR /m^3 fuel (see Table C7.4) with the amount of fuel consumed, which is 240 m^3 in all the scenarios. Adding the cost of a tax to the already unprofitable fishery only increases the net loss. Naturally, the high national tax has the largest impact, whereas the effect of the other tax policies is less significant. In the national tax scenario the fuel tax implies an 18% increase in costs, and a subsequent 69% increase in loss.

Table C7.7. Economic performance under current management in the Gulf of Bothnia salmon fishery, 2010

	Current management			
	1. No fuel taxes	**2. National exemptions removed**	**3. EU 2009 CO_2 quota price**	**4. Stern quota price**
Fuel				
Cubic meters (m^3)	240	240	240	240
Added cost (EUR 1,000)	0	150	7	34
Economic data (EUR 1,000)				
Landings value	609	609	609	609
Costs	825	975	832	859
Net profit	-216	-366	-223	-259

Table C7.8 shows the effects of the different fuel tax policies on the selected indicators under optimal management. These effects can be compared to the current situation, which is depicted on the left hand side of the table. Note that the optimization results apply to the River Tornionjoki stock fishery, and cannot therefore be directly generalized to other Baltic salmon fisheries. Moreover, the current situation is represented here by data for this specific stock; thus the fishing effort is approximately one third of that in the whole Gulf of Bothnia. The current effort level used here is the mean yearly effort during the period 2000–2010.

Maximizing net present value would imply a 52% decrease in effort from the current level. Introducing fuel taxes would lead to even larger decreases in effort. The national fuel tax would cut effort by up to 74% compared to the Benchmark scenario. The difference between the EU and Stern scenarios and the Benchmark are less significant. The changes in number of fishers/vessels are estimated based on the changes in effort, and should be considered with some caution. However, the mean age of existing fishers is high and recruitment of new labor to the industry is difficult. Therefore, sizable decreases in employment may be a realistic consequence in the future, even under current management measures.

The net present value gives the value of the fishery over the 50 year timespan. As can be seen from Table C7.8, the current fishery has a negative NPV of EUR 5,000. This is in line with the results we obtained from the whole Gulf of Bothnia fishery, and, although given that the River Tornionjoki stock comprises about one third of the whole fishery, this loss seems quite moderate in comparison. Looking at scenarios 1–4, the model suggests that by moving to optimal management the fishery could be made slightly profitable. The profit is EUR 42,000 when maximizing NPV in the Benchmark scenario. The EU and Stern scenarios result in somewhat smaller rents. However, in the national tax scenario the resource rent is almost completely depleted. A quick sensitivity analysis reveals that the NPV is zero when the unit cost of fishing is EUR 52 or above.

The fuel consumption and subsequent CO_2 emissions are estimated based on effort, when a given fuel consumption per gearday is assumed. When maximizing NPV, both kg catch/liter and landing value/liter increase. There occurs an additional increase in these indicators when the national fuel tax is imposed. In the EU scenario, which has the lowest tax, there is no movement in these indicators compared to the Benchmark. With the slightly higher Stern tax, kg/catch is again equal to the Benchmark, whereas landing value/liter moves a fraction up.

Finally, the table shows the harvest level and stock size at which the fishery stabilizes in the long run. There is a notable change from the current situation to the optimal. Again, there is little difference between the two low tax scenarios and the Benchmark, whereas the low effort explains the modest harvest level in the national tax scenario.

Table C7.8. Long-run effects in scenarios 1–4 of fuel taxes on net present value, fishing effort, fuel consumption and CO2 emissions. River Tornionjoki stock, 2010

		Optimal management			
	Current situation	1. No fuel taxes	2. National exemptions removed	3. EU 2009 CO_2 quota price	4. Stern quota price
Fleet					
Effort (trapnet days)	6,858	3,312 (-52%)	857 (-74%)	3,190 (-4%)	2,751 (-17%)
Number of fishers/vessels	59	29	7	28	24
Economic data (EUR 1,000)					
Net present value	-5	42	3	39	29
Fuel					
Cubic meters (m^3)	95	46	12	44	38
CO_2 emissions (tonnes)	221	106	28	103	88
Kg catch/liter	0.30	0.33	0.34	0.33	0.33
Landing value (EUR)/liter	1.31	1.40	1.46	1.40	1.41
Other					
Harvest (nr. of fish)	4,674	2,411	652	2,328	2,023
Harvest (1,000 kg)	28.84	14.88	4.02	14.36	12.48
Stock size (1,000 fish)	155	161	164	161	161

C7.7 Discussion

The aim of this study is to assess the effects of fuel taxation on the coastal salmon fisheries in Finland. The fishery is currently unprofitable, and therefore not fit to bear the burden of additional costs imposed by a fuel tax. However, the results of this study suggest that by moving to optimal management, i.e. by adjusting the fishing effort to an efficient level, the fishery could be made profitable. Furthermore, an optimally managed fishery would have a positive net present value even if fuel taxes were imposed, and could thus potentially pay for its external costs caused by CO_2 emissions. An optimal fishery will be more fuel efficient than in the present situation.

It should be noted that the Finnish national tax is especially high in this case, and will therefore have a bigger impact on the results than in the other case studies. Further, the largest part of this tax consists of an energy content tax. If, in this context, we view the taxation as a way of getting the fishery to pay for its externalities caused by CO_2 emissions, this tax is perhaps not the optimal. In the EU and Stern scenarios, where the tax only internalizes CO_2 costs, the optimally managed fishery seems more robust to changes in fuel costs.

Although the salmon fishery could be made profitable through a movement to optimal management, the present high fishing costs and low fish market values will not allow any substantial profits to be gained. For example, boycotts of Baltic salmon, initiated by WWF, have resulted in a decline in producer prices of salmon. Additionally, rising fuel costs have had a notable effect on both coastal and offshore fishery businesses. Overall, investments in Finnish coastal fisheries have increased, but this has not led to increased profits (STECF 2012).

The results of this study apply to the River Tornionjoki salmon stock, and they are therefore only directional with respect to other Baltic salmon fisheries. The River Tornionjoki stock counts among the more vital salmon stocks in the Baltic Sea. Nonetheless, coastal fisheries are not stock-specific and might therefore pose a threat to weaker salmon stocks. According to advice given by ICES (2013), fishing effort in such fisheries should be reduced. This is in line with our policy recommendations. Additionally, our results indicate that compared to the Gulf of Bothnia fishery as a whole, the River Tornionjoki stock fishery is economically more sound. This would further support a movement to more stock-specific harvesting. However, since this sort of harvesting is possible only in rivers and estuaries, this would probably have serious implications for the commercial coastal fisheries. The low profitability of commercial salmon fisheries and the high status of recreational fishing in rivers have been the cause of continuous debate among different stakeholders in Finland and other Nordic countries.

References

Biomass Energy Centre 2013. Carbon emissions of different fuels. http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL

European Commission 2012. Legislation: European Commission proposes to overhaul energy taxation rules. http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/legislation/index_en.htm

FAO 2009. The state of world fisheries and aquaculture 2008. FAO Fisheries and Aquaculture Department. Food and Agriculture Organization of the United Nations Rome, 2009.

FGFRI 2010. Commercial marine fishery in 2010. Statistics 3/2011. Finnish Game and Fisheries Research Institute, Helsinki

Finnish Petroleum Federation. 2013. Consumer price update. http://www.oil.fi/fi/tilastot-1-hinnat-ja-verot/11-oljytuotteiden-kuluttajahintaseuranta

Holma, Maija., Kulmala, S. & Lindroos, M. Optimal management of conflicting species: Grey Seal (Halichoerus grypus) and Atlantic salmon (Salmo salar) in the Northern Baltic Sea.

ICES 2012. Report of the Baltic salmon and trout assessment working group (WGBAST). 15–23 March, Uppsala, Sweden. ICES CM 2012/ACOM:08. 353 pp.

ICES 2013. Advice 2013. Salmon in Subdivisions 22–31 (Main Basin and Gulf of Bothnia). ICES Advice 2013, Book 8.

Kulmala, S., Levontin, P., Lindroos, M., Michielsens, C., Pakarinen, T. & Kuikka, S. 2008a. International management of the Atlantic salmon fisheries in the Baltic Sea. University of Helsinki, Discussion papers n:o 22.

Kulmala, S., Laukkanen, M. & Michielsens, C. 2008b. Reconciling economic and biological modeling of migratory fish stocks: Optimal management of the Atlantic salmon fishery in the Baltic Sea. Ecological Economics, 64: 716–728.

Martini, R. 2012. Fuel tax concessions in the fisheries sector. OECD Food, Agriculture and Fisheries Papers, No. 56, OECD Publishing.

Ministry of Agriculture and Forestry 2005. Professional fishing. http://www.mmm.fi/en/index/frontpage/Fishing,_game_reindeer/Fisheriesindustry/Professional_fishing.html

Ministry of Finance 2009. Taxation in Finland 2009. Ministry of Finance publications 7/2009. http://www.vm.fi/vm/en/04_publications_and_documents/01_publications/075_taxation/20090504Taxati/taxation_2009_netti%2bkannet.pdf

Ministry of Finance 2012. Nestemäisten polttoaineiden valmisteverotus. https://www.vm.fi/vm/fi/10_verotus/05_valmisteverotus/06_nestemaisten_polttoaineiden_valmistevero/index.jsp

National Board of Customs 2012a. Energy taxation. Customer bulletin 21, February 2012.

National Board of Customs 2012b. Alusten polttoaineiden verottomuus. Customer bulletin 12, February 2012.

OECD 2011. Environmental taxation: A guide for policy makers. Policy Brief based on the OECD book Taxation, Innovation and the Environment (2010).

OECD 2012. OECD Review of Fisheries 2011: Policies and Summary Statistics, OECD Publishing.

Sumaila, U.R., Teh, L., Watson, R., Tyedmers, P. & Pauly, D. 2006. Fuel subsidies to global fisheries: Magnitude and impacts on resource sustainability. In Sumaila, U.R. & Pauly, D. (eds.), Catching more bait: A bottom-up re-estimation of global fisheries subsidies (2nd version, 2007). Fisheries Centre research reports, 14(6), pp. 38–48. Fisheries Centre, the University of British Columbia, Vancouver, Canada.

STECF 2012. The 2012 Annual Economic Report on the EU Fishing Fleet (STECF-12-10). Scientific, Technical and Economic Committee for Fisheries (STECF). http://stecf.jrc.ec.europa.eu/documents/43805/366433/12-08_STECF+12-10+-+AER+EU+Fleet+2012_JRC73332.pdf

Stern, N. 2006. The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge, UK.

Sterner, T. 2007. Fuel taxes: An important instrument for climate policy. Energy Policy, 6: 3194–3202.

norden

Nordic Council of Ministers

Ved Stranden 18
DK-1061 Copenhagen K
www.norden.org

TemaNord 2014:533

Reducing Climate Impact from Fisheries

Few doubt the impact from human activities on global warming and the negative consequences of rising temperatures for both terrestrial and marine ecosystems. Efficient policy instruments are needed to change the development. This report uses empirical models to analyse how CO_2 emissions, fleet structure, economic performance, and employment opportunities are affected by imposing management instruments to reduce climate impacts. These instruments include both fisheries management such as larger stock levels and more efficient fleets, and energy policy such as fuel taxes or CO_2 trading schemes. To get a representative view of the Nordic fisheries, the analysis contains case studies from all the Nordic countries: Sweden, Denmark, Norway, Iceland, Greenland, the Faroe Islands and Finland. The fleet segments analysed range from coastal small-scale trap nets to large off-shore trawlers.

TemaNord 2014:533
ISBN 978-92-893-2783-1
ISBN 978-92-893-2784-8 (EPUB)
ISSN 0908-6692

9 789289 327831