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Resource Rent in Norwegian Fisheries

Trends and policies

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Abstract:
A nation's natural-resources wealth can be estimated via the System of National Accounts (SNA). Because the values of all parameters entering the calculation are conditional on the existing management regime, the optimal value of the natural resources may be masked. This is the case for the Norwegian fishery sector. Using the SNA the Norwegian fisheries contributed negatively to the actual national wealth in the period 1984-2014 with the exception of 2010-2011. By exploring the development of the actual resource rent for the same time period applying the SNA, we find that the rent has increased over time as a result of a consolidation of the industry. However, the costs of extracting the fish is much higher than necessary, implying that the resource rent is lower than it could have been, and this means that we are in a situation of resource waste. Using a numerical optimization model we find the contra factual resource rent if 2011's quotas where harvested efficiently with the available technology to be close to 9.3 billion NOK, which is 7 billion NOK more than the observed resource rent in 2011.

Keywords**:** fishery economics, resource rent, fish quotas

JEL classification: Q22, Q28

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Sammendrag

Vi kan estimere den faktiske verdien av en naturressurs slik som fisk, skog og mineraler ved å bruke nasjonalregnskapet. Da benytter vi gjeldende kostnader, priser og tall for fangst/høstning/utvinning. Ressursrenten tilsvarer det som er igjen etter at alle kostnader er trukket fra fortjenesten, også kostnader ved å ha investert i fast kapital. Verdien av ressursrenten som fremkommer er gitt dagens forvaltningsregime og vil blant annet avhenge av markedsstruktur, teknologi og politiske føringer. Økonomisk teori tilsier at denne skulle være positiv dersom forvaltingen hadde optimal verdiskaping som målsetting.

I dette arbeidet studerer vi ressursrenten i norske fiskerier. Ved å bruke tall fra nasjonalregnskapet finner vi at den faktiske ressursrenten i norske fiskerier var negativ i perioden fra 1984 til 2014 med unntak av 2010-2011. Samtidig finner vi at ressursrenten gradvis har økt i samme periode. Ved å dekomponere den faktiske ressursrenten for denne perioden finner vi at økningen i all hovedsak skyldes reduserte kostnader som følge av færre fiskere og færre fartøy.

For å få et anslag på hva verdiskapningen i sektoren kunne ha vært, beregner vi den optimale ressursrenten for norske fiskerier ved hjelp av en numerisk modell. For 2011 finner vi at den optimale ressursrenten er 9,3 milliarder NOK. Dette er om lag 7 milliarder mer enn den faktiske renten samme år enten vi måler den utfra tall fra nasjonalregnskapet eller ut fra Fiskeridirektoratets lønnsomhetsanalyser. Forskjellen på 7 milliarder er et mål på kostnadene ved dagens forvaltningsregime. Fordi ressursrenten kan økes med lavere antall fiskere og færre fartøy i sektoren, er vi per definisjon i en situasjon med ressurssløsing gitt at både humankapitalen og realkapitalen har en alternativ verdi i andre sektorer. Ved å gjøre en enkel justering av forskjellen mellom optimale og faktiske inntekter og kostnader lik det vi fant for 2011, viser resultatene at den optimale ressursrenten for 2010 og 2012 henholdsvis ligger 6,9 og 7,4 milliarder NOK over den faktiske renten. Selv om dette er en veldig enkel tilnærming er ikke beløpene langt fra de 7 milliardene vi fant var kostnadene ved å opprettholde forvaltningsregimet i 2011.

Vi utfører en rekke følsomhetsberegninger og finner at den optimale ressursrenten i 2011 er relativ stabil under ulike forutsetninger. Siden vi ikke har data for de mest effektive fartøyene i en fartøygruppe, kan vi ikke simulere en situasjon der alle fartøyene i en gruppe er like den mest effektive. Således får vi en lavere optimal ressursrente enn man kunne fått i en situasjon der fiskerne tok i bruk den mest effektive teknologien.

Vi har ikke funnet tall for hvor mye tid et spesielt fartøy i en fartøygruppe bruker på å fange et spesielt fiskeslag. Dette kan påvirke de variable kostnadene for ulike fartøygrupper og først og fremst gjøre våre resultater om optimal fordeling av fangsten på de ulike gruppene mer usikker.

Til slutt vil vi også understreke at noen fartøygrupper opp igjennom årene har hatt større mulighet til å effektivisere innenfor det til enhver tid gjeldende regelverket enn andre. Disse fartøygruppene vil dermed komme ut med relativt lavere kostnader enn de som har hatt mindre mulighet til å velge teknologi og kapasitet.

1. Introduction

The UN Report "Our common future" (1987) defines *"sustainable development"* as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. Several sets of indicators have been proposed in order to uncover unsustainable economic development. One approach is the so-called *capital approach to sustainable development*, which is based on calculating national wealth; see e.g. Alfsen and Greaker (2007). The rationale is that "consumption" must be "produced" every year from the use of certain capital stocks e.g. manmade capital, human capital and natural resource capital. In order to uncover unsustainable practices we need to periodically monitor the state of the capital stocks. Assuming that capital stocks can substitute for each other, a rather strong assumption, sustainable development only requires that the value of the capital stocks together, that is national wealth, is kept constant (or is growing).

Statistics Norway has been involved in calculating Norwegian national wealth for several years based on data from the System of National Accounts (SNA). Statistics Norway (2014) shows that national wealth per capita has been on an increasing trend throughout the period 1984 to 2013[1], which is an indication of sustainability. National wealth only includes the inputs used to produce net national income (NNI) as measured and defined in the SNA. These comprise human capital stocks, physical capital stocks, financial assets and natural resource stocks. The net income from a resource is coined resource rent. The resource rent is the additional income a nation/region/user obtains from having the exclusive right to exploit a natural resource. The resources included in the Norwegian SNA are the renewable natural resource sectors; agriculture, forestry, aquaculture, fisheries and hydropower, and the nonrenewable natural resources; oil, gas and minerals. While both the value of physical capital and foreign financial holdings is given directly in the SNA, the values of the natural resource stocks must be computed. The contribution of each resource stock to national wealth is given as the present value of the future stream of resource rents.

Despite everyone's perception of Norway being very rich in natural resources, the calculations show that apart from oil and gas, natural resources only make up a tiny part of Norwegian national wealth. For instance, in the calculations for 2013, Statistics Norway (2014) found that human capital comprised 72 percent of national wealth, while oil and gas and physical capital comprised approximately 9 and 13 percent, respectively. Financial wealth was around 6 percent of national

[1] There were temporary setbacks in wealth per capita in 1989, 2003, 2008 and 2009.

wealth, while the contribution of the renewable natural resources taken together was less than one percent, and the positive estimate was to a large extent due to the value of hydropower.
This paper performs an investigation of resource rent in Norwegian fisheries. First we show the development of the components of resource rent over time from 1984 to 2014 based on SNA in order to explain why the actual resource rent has been low. The resource rent was negative in all years except 2010 and 2011. However, the actual resource rent has gradually increased since 1984. Compensation to employees is the largest cost component affecting the rent of Norwegian fisheries, and this cost is much larger than the return on fixed capital and capital consumption. Total revenues in the sector have remained fairly constant, and the increase in resource rent is mainly due to lower total costs of labor and capital. Thus, the actual resource rent has increased mainly due to consolidation indicating that more of the fisheries income is distributed on fewer vessels and fishers.

In order to estimate the optimal value of the Norwegian natural resources, this paper continues by calculating a contra factual value of the resources given an optimal management practice. This has previously been calculated for Norwegian fisheries (see for example Hanneson, 1996; Steinshamn 2005), but the last time was several years ago. We define optimal as the maximum resource rent in 2011 applying catch quotas, prices, costs and technology in 2011 in Directorate of Fisheries (2012). Using a numerical optimization model we estimate the contra factual value of the Norwegian fisheries and find that the resource rent in 2011 could have been 7 billion NOK higher than the actual rent. If the resource rent in the fishery sector can be increased by e.g. fewer fishers and vessels than with the present management, we have per definition a situation with resource waste in the fishery sector as well as less value creation elsewhere as both human and fixed capital have an alternative value in other sectors (see definition of resource rent in Section 3). Hence, 7 billion NOK is the cost *only* in the fishery sector in 2011 of having the present management system.

This paper is organized as follows: Section 2 describes the Norwegian policy regime. Section 3 gives an overview of how the resource rent is calculated using the SNA and Section 4 presents the actual resource rent in the fisheries over the last three decades. In Section 5 we take a closer look at the actual and optimal resource rent in 2011 and in Section 6 we describe the data. Section 7 shows the optimization results and in Section 8 we perform various sensitivity analyses. Section 9 is a discussion of the results and Section 10 concludes.

2. The Norwegian Policy Regime

The Marine Resources Act of June 6, 2008 no. 37 states that "the wild living marine resources belong to the Norwegian society as a whole". The Act requires that resource management uses a precautionary approach, an ecosystem approach, and that there is a safe use of gear. The Act also mandates that resources should be allocated to help ensure employment and settlement in coastal communities and that there should be an optimal utilization of resources that is adapted to marine value creation, markets and industries.

In 2011 Norwegian fisheries had 10220 full-time fishers, 2548 part-time fishers and 6250 vessels (Directorate of Fisheries, 2015). Together, they landed approximately around 2 million tons of fish (excl. crustaceans, shells, seaweed and sea tangle). These numbers can be compared to the situation in 1984 – the first year of our resource rent calculations. In 1984 Norwegian fisheries had 22861 full-time fishers, 6767 part-time fishers and 24078 vessels. However, their landings in tons were approximately the same as in 2011. The downward trend in the number of fishermen and vessels is partly due to official Norwegian policy. The Norwegian fishery management underwent a large transformation during the last part of the 19 century. Spurred by the collapse in the Atlanto-Scandian herring stock in the late 1960s the Norwegian Government started to restrict entry into more and more fisheries. At the same time they introduced measures such as scrapping subsidies in order to reduce the overcapacity in the fleet. The excess capacity was a result of technological progress, for instance the introduction of fish finding equipment and mechanical purse seines (Hanneson, 2005).

The fishery management regime in Norway is complex. For as much as about 90 percent of fisheries, Norway's annual total allowable catch (TAC) is determined in bilateral and multilateral negotiations with other nations. For the remaining part of the fisheries national authorities set TACs independently based on expert advice. For each stock, the overall TACs are allocated by the Norwegian government and politicians to different vessel groups, and further distributed within the vessel group among the vessels holding the necessary licenses to participate. All fishing vessels need to have a commercial license, and only Norwegian citizens and active fishers (participated at least three of the last five years) may apply for a commercial license. The rationale for this regulation is to ensure that the returns on the fisheries activities go to the active fishers in the coastal communities.

There is a distinction between vessel groups that belong to the costal fleet and those that belong to the ocean-going fleet when allocating TACs. Vessels in the costal fleet receive an annual permit based on the TAC, which is not tradable in any way. The boats in the ocean-going fleet have individual vessel quotas, which may last for several years, and which to some extent is tradable. The individual vessel quotas only imply a right to fish a certain proportion of the overall TAC allocated to the ocean-going vessels. Moreover, the authorities can withdraw permits and licenses if conditions are not met, and can also allocate new licenses and permits. Licenses and annual permits are not tradable across fleets and vessel categories, as they are issued to and associated with a given vessel type. However, when vessels are traded within a vessel type, the license and annual permit follow the vessel when permission has been granted - with certain restrictions - by the authorities.

In order to reduce overcapacity in the fishing fleet, a system for quota consolidation in the fishing fleet called the Structural Quota System was introduced in 2004 (The Norwegian Ministry of Trade, Industry and Fisheries, 2007). The main principle of the Structural Quota System is that a vessel owner can buy another vessel and transfer the other vessel's quota (a structural quota) to his/her own vessel. The vessel that hands over the structural quota must then be scrapped. In this way the system facilitates increased vessel profitability. However, other considerations are also taken into account, including regional policies. A geographically dispersed fishing fleet must be maintained in order to support coastal communities and their cultural heritage. Some restrictions are therefore implemented, including maximum quota per vessel, geographically limited markets, transactions only within vessel groups and mandatory scrapping. A major shift took place during the period 2004 to 2006 when some trade across vessel types became permitted. In particular, this reduced the fleet of the trawlers, a type of ocean-going vessel. According to the Norwegian fishery authorities, the Structural Quota System resulted in the following degree of traded quotas in selected vessel groups:

Table 1. Structural quotas in different vessel groups during the last few years[2]

Vessel group	Percentage traded structural quotas
Purse seiners herring	18.6 per cent
Pelagic trawlers	54.7 per cent
Coastal vessels herring	39.6 per cent
Cod trawlers	57.0 per cent
Ocean-going line fishing vessels for cod	57.1 per cent
Coastal vessels cod	22.2 per cent

We see that the amount of trading is larger among the trawlers and ocean-going line fishing vessels. As far as we can understand, only the ocean-going part of the fishing fleet has undergone large structural changes. The coastal fishing fleet still receives a large share of the TAC for many fish stocks, and the incentives for reducing the number of boats are much weaker within this segment.

[2] Source: The Norwegian Ministry of Trade, Industry and Fisheries (2015).

3. Calculation of the Actual Resource Rent of Fisheries using National Accounts

The calculation method of resource rent in Norwegian natural resource sectors is presented in Table 2. Statistics Norway's calculation of the resource rent (see e.g. Greaker, Løkkevik and Aasgaard Walle, 2005) in marine fisheries is comprehensive in that it includes full and part-time fishers, and the net revenue from the capture of all wild marine organisms[3], by both commercial and non-commercial vessels. Statistics Norway calculates a factor, which is used to scale-up the basic value from the commercial vessels participating in the profitability analysis in Directorate of Fisheries (2012) to encompass the whole vessel fleet. We simply downscale this basic value with the same factor to get comparable numbers between national accounts and the Directorate of Fisheries (2012).

Table 2. Calculation of the actual resource rent

Sign	Term
+	Basic value of production
-	Intermediate uses
+	Taxes on products
-	Subsidies on products
=	Gross product
-	Non-Industry specific taxes
+	Non-Industry specific subsidies
-	Compensation of employees
-	Return on fixed capital
-	Capital consumption
=	Resource rent of the sector

The basic value of production is equivalent to total revenues. The intermediate uses are goods and services consumed or used up as inputs in production. There were no product specific taxes or subsidies in the time period considered in this paper. While there has been and still is in place a fuel tax exemption for fishing vessels, this subsidy is not product specific and is therefore not included in the resource rent calculations.

When calculating compensation of employees and return to fixed capital, it is a goal to use wage rates and rates of return that reflect the alternative value of both the fishers and the capital employed in the sector. Statistics Norway calculates the compensation of employees as the number of hours worked times the average mainland wage rate for the non-natural resource industries, and the return on fixed capital is four per cent of the value of the stock of fixed capital. It is necessary to include income for

[3] Including crustaceans, shells and seaweed. Aquaculture is not included.

the vessel owners, as their income is not part of the wages in the profitability survey, but part of the operating profit.

Care must be taken when deciding which subsidies and taxes to include in the calculation of the resource rent and how to include them. Taxes on products, can be regarded as a part of the value that is created by the industry when the resource is extracted, while a product specific subsidy can be seen as part of the costs of extracting the resource. A product specific tax paid by the specific resource industry must therefore be added to the resource rent, while a product specific subsidy must be subtracted. There are no product specific taxes or subsidies in Norwegian fisheries. According to Eurostat (2001) industry specific taxes and subsidies shall not be included in the calculation of the resource rent because they are simply a transfer of the resource rent between the Government and the industry and do not affect the bottom line value of the resource rent. However, industry specific taxes and subsidies may affect the structure of the industry. For instance, lowered financing costs to fishers taking up loans to purchase a fishing vessel will over time result in overcapitalization and "too many boats chasing too few fish" and thus contribute to reduced resource rents. Currently, Norwegian fishers are exempt from fuel taxes, which contribute to inefficient use of fossil fuels in the industry and increased CO_2 emissions. The cost, not including the tax administration costs, to the Norwegian Government of the fuel-tax exemption was estimated to NOK 999 million in 2011 (Isaksen, Hermansen and Flaaten, 2015). According to Eurostat (2001) non-industry specific taxes shall be subtracted and non-industry specific subsidies shall be added because these transfers, being independent of industry, can be considered standard costs/income from doing business. An example of non-industry specific tax is firms' social security contributions. However, as industry specific taxes and subsidies may affect the resource rent, in addition to that the fact that the distinction between what is industry specific and what is not is sometimes vague, we chose to leave all taxes and subsidies out of our calculations. Total taxes and subsidies are generally between 3 and 7 per cent of the gross product as from 1995 and will often more or less cancel each other out. The net effect will nevertheless be small and will only affect our results in a minor way.

4. The Actual Resource Rent in Norwegian Fisheries over the Last Decades

Figure 1 shows the components of the resource rents in Norway for the period 1984 – 2014 as calculated using national account numbers. Gross product is total revenue less the value of intermediate uses as explained above. The actual resource rent is negative for all years except for 2010 and 2011[4]. The reason for the negative rent is primarily the high level of compensation of employees compared to the gross product. The resource rent is generally on an increasing trend from the late 1980s, although there are yearly variations due to changes in the gross product (i.e. price and/or catch). The increase in actual rent is above all due to lower compensation of employees and to some extent reduced capital consumption and return on fixed capital.

Figure 1. The components of resource rent in Norwegian fisheries 1984-2014

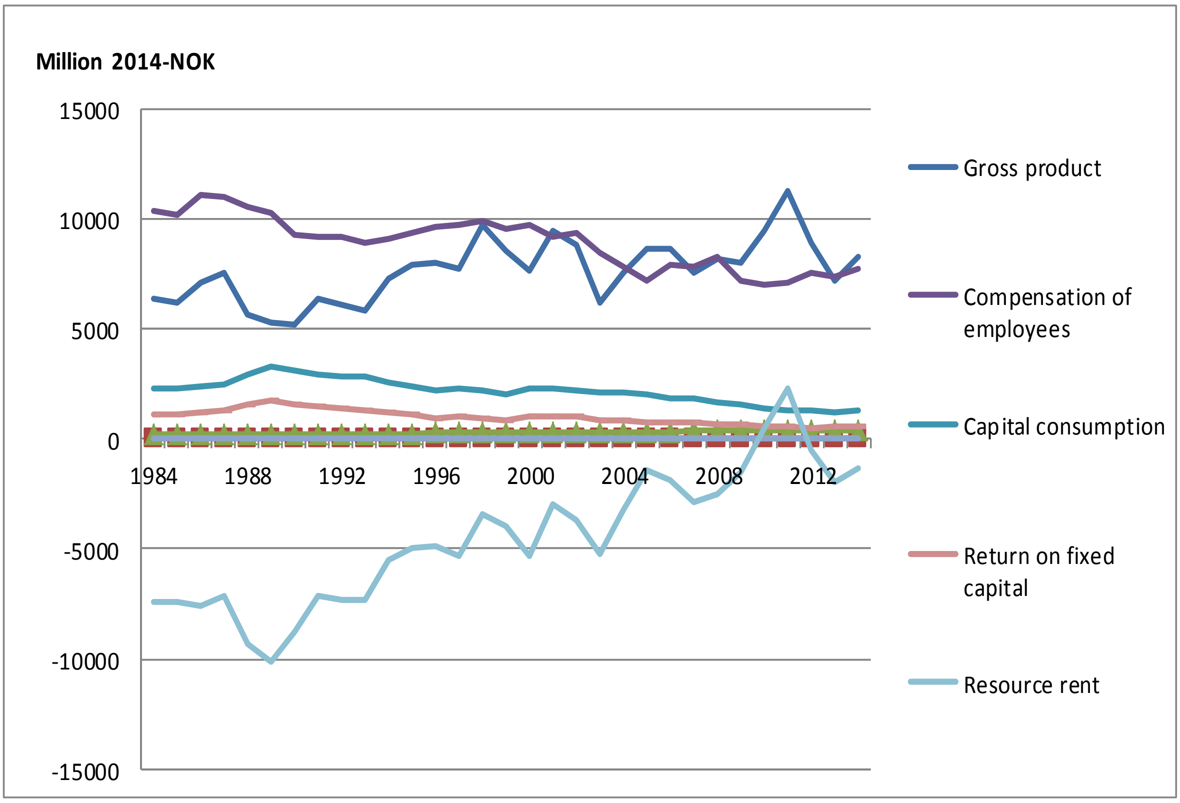
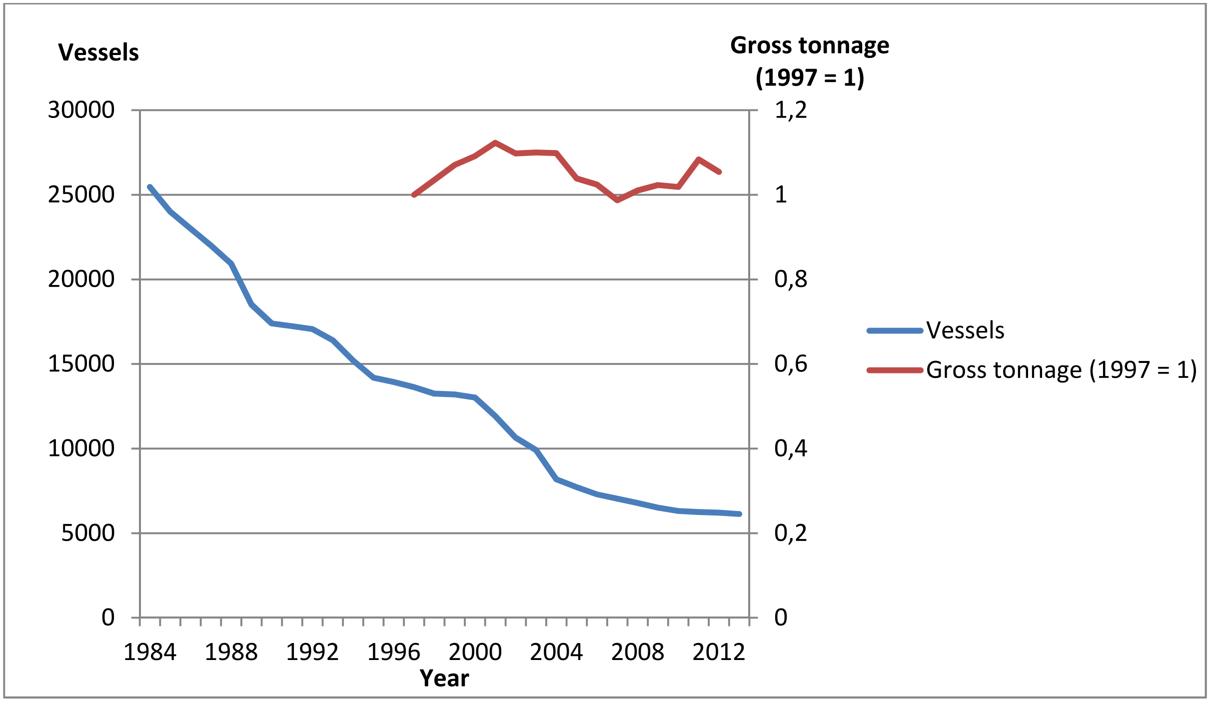


Figure 2 shows that capital consumption and return on fixed capital has declined in line with a lower number of vessels, although the gross tonnage[5] is more or less the same.

[4] The resource rent according to Statistics Norway and the national accounts was 2.153 billion NOK in 2011. However, applying the numbers in Directorate of Fisheries (2012) the rent is around 2.050 billion NOK. Part of the reason is different ways of calculating fixed capital and the number of man-years.

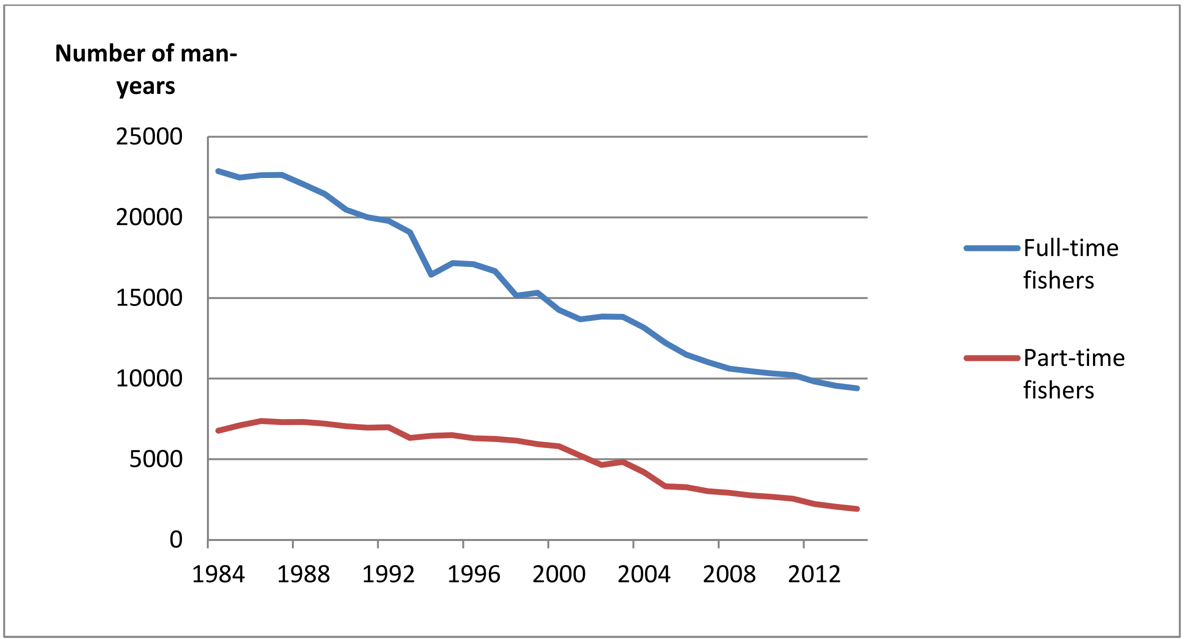
[5] Gross tonnage is a measure of the "total volume of all enclosed spaces of the ship". The measure for Gross tonnage is defined by *The International Convention on Tonnage Measurement of Ships* and was adopted by the International Maritime Organization in 1969. We were not able to find older Gross Tonnage numbers for Norwegian vessels than 1997.

Figure 2. The number of vessels 1984-2013 and gross tonnage 1997-2012 in Norwegian fisheries



Even if the number of man-years for the full-time and part-time fishers has declined by around 60 and 72 per cent since 1984, respectively, as shown in see Figure 3, total compensation of employees is only 30 per cent lower in 2014 compared to the early 1980s due to increases in real wages.

Figure 3. The number of man-years in Norwegian fisheries 1984-2014



5. A Closer Look at the Actual and Optimal Resource Rent in 2011

The resource rent obtained depends on the management regime including (1) the total allowable catch (TAC) and (2) the technology used to harvest the TAC, that is the types and numbers of vessels. In pure open access regimes, fish stocks become overharvested and may become extinct (Clark, 1990). Setting and enforcing catch quotas is one way to secure viable fish populations. Ideally, the catch quota, i.e. the TAC, should be low enough so that fish stocks are capable to regenerate between harvests and therefore can be harvested in perpetuity. This TAC level is typically denoted the Maxium Sustainable Yield (MSY) (Clark, 1990). MSY is purely based on biological parameters. The optimal harvest level that also takes economic parameters into account is called the bioeconomically optimal harvest level. We do not attempt to estimate the bioeconomically optimal harvest level in this paper but assume that the TACs in 2011 were set to the fish stocks' MSY-levels.

For a given TAC the number of vessels may be too large or the vessels used may be too inefficient to maximize the resource rent. In addition, the allocation of the TAC geographically and among vessels types may lead to further loss of resource rent.

As shown in Figure 1 and Table 3, Statistics Norway estimate the actual resource rent in Norwegian capture fisheries to 2011-NOK 2.153 billion. If we instead calculate the resource rent applying data from the profitability survey by the Directorate of Fisheries, the actual resource rent was 2011-NOK 2.050 billion. The reason for the divergence in resource rent estimates is different ways of calculating fixed capital and the number of man-years applying the national accounts compared to the accounts in the profitability survey.

Table 3. Estimates of the actual resource rent.

Resource rent -estimate	Resource rent (billion NOK)
SNA: Professional full-time fishers that earn a certain minimum annually	2.153 billion NOK
Profitability Survey: Professional full-time fishers that earn a certain minimum annually	2.050 billion NOK
Profitability Survey: Ten most valuable fish species	1.453 billion NOK

To be included in the 2011 profitability survey vessels had to earn a certain level of income from their fishing operation[6]. If limiting ourselves to the ten[7],[8] economically most important species the actual resource rent was 2011-NOK 1.453 billion.

Given today's TACs, number and types of vessels, and labor force we now move on to find an estimate of the optimal resource rent if the catch could be redistributed among vessels according to the groups that receive the best price for the catch, have the lowest cost and where vessels operate at their maximum biologically and technically possible season length. To do this we use a linear programming model based on Steinshamn (2005). The model maximizes net revenues, that is maximizes resource rent, given the total allowable catch for each fish species *i*, TAC_i, which we assume is set to a sustainable level and the fixed catch capacity per vessel in vessel group *j* given by technology, KAP_j, by choosing the optimal number of vessels in each vessel group N_j and the total catch of fish species *i* for vessel group j, $Y_{i,j}$. The model is specified as:

(1) $$RR = \max_{N_j, Y_{i,j} \geq 0} \sum_{i=1}^{N}\sum_{j=1}^{M}(p_{i,j} - f_{i,j}VC_j)Y_{i,j} - \sum_{j=1}^{M} N_j FC_j$$

Subject to:

(2) $$\sum_j Y_{i,j} \leq TAC_i \qquad i = 1,\ldots,N$$

(3) $$\sum_i Y_{i,j} \leq KAP_j N_j \qquad j = 1,\ldots,M$$

(4) $$N_j \geq 0 \ , \ Y_{i,j} \geq 0$$

Here $p_{i,j}$ is the price received, VC_j is the variable cost, $f_{i,j}$ is the time/effort coefficient, and FC_j is the fixed cost. Notice that the price depends both on species and vessel group, in other words, all vessels do not receive the same price for the same fish. The model also includes by-catch relationships and seasonal catch-limits (Steinshamn, 2005), which we discuss in further the data section. Politically determined constraints, such as the distribution of catch between coastal and ocean-

[6] To be included in the activity survey, earnings must be at least NOK 471,000 for vessels 0-9.9m, NOK 784,000 for vessels 10-10.9m, NOK 1,177,000 for vessels 11-14.9m and NOK 2,353,000 for vessels 15m and above.

[7] These species are cod, herring, haddock, saithe, mackerel, cusk, ling, blue whiting, capelin and shrimp. In Norwegian: torsk, sild, hyse, sei, makrell, brosme, lange, kolmule, lodde og reke.

[8] We focus on these ten species because they on average contributed to 90 per cent of the basic value in the years 2006-2013. 2006: 89 per cent, 2007: 91 per cent, 2008: 91 per cent, 2009: 89 per cent, 2010: 89 per cent, 2011: 91 per cent, 2012: 91 per cent and 2013: 90 per cent (Directorate of Fisheries, 2015).

going vessels are omitted from this model but are added in the sensitivity analysis. The model in equations (1)-(4) is calibrated for the ten economically most important species with 2011 data for prices, costs, quotas and vessel groups.

6. Data

In parameterizing our model we consider the thirteen vessels groups (see Table 4) that were included in the 2011 profitability survey of the fisheries (Directorate of Fisheries, 2012).

Table 4. Vessel groups and number of fishers employed in each vessel group.

Vessel group number	Vessel description	Geographic regions of operation in Norway	No. vessels	No. employed
1	Coastal vessels using conventional gear. Vessels below 11 meters quota length	Mainly in the north, some south.	611	1039
2	Coastal vessels using conventional gear. Vessels 11-14.9 meters quota length	Mainly in the north, some south.	293	791
3	Coastal vessels using conventional gear. Vessels 15-20.9 meters quota length	Mainly in the north, some south	121	799
4	Coastal vessels using conventional gear. Vessels 21 meters quota length and above	All	37	392
5	Ocean-going vessels using conventional gear	All	35	1061
6	Trawlers. Vessels with cod trawling and/or shrimp trawling license	All	39	1556
7	Coastal shrimp trawlers	All	80	224
8	Other trawlers (fishing for saithe, lesser and greater argentines and more)	All	4	82
9	Coastal vessels using seine. Vessels below 11 meters quota length	All	43	77
10	Coastal vessels using seine. Vessels 11-21.35 meters quota length	All	93	409
11	Coastal vessels using seine. Vessels 21.36 meters quota length and above	All	62	552
12	Purse seines	All	80	1192
13	Pelagic trawlers	South of Norway	27	215
			1525	8389

These vessel groups harvested a total of 2 million metric tons in 2011 when the first-hand value was estimated to NOK 14.6 billion. This corresponds to about 91 percent of the total first-hand value in

Norwegian fisheries in 2011[9]. For TAC we use the actual total Norwegian catch in 2011 for the ten economically most important species. The TAC for these ten species was 1.83 million tons in 2011 (see table A1 in Appendix A), and constitute 71 percent of the actual total resource rent when we apply total catches in the profitability survey (see Table 3).

Fish prices, $p_{i,j}$, for each vessel group and species, which are provided in Table A2 were also found in the 2011 profitability survey (Directorate of Fisheries, 2012). We measure the present capacity, KAP_j, of a single vessel in each vessel group as follows: Actual catch is first divided by number of days in operation listed in the profitability survey. This capacity is secondly multiplied with the potential number of days in operation (see Table A3). This potential capacity is further downscaled due to biological and/or technical reasons when calculating the adjusted potential variable costs for the various species/vessel groups (see below). We apply the average catch of a vessel as we have no data for the most efficient vessels in each group. Hence, our optimal resource rent is lower than it would have been if we were a situation where all fishers adopted the most efficient technology.

Actual variable costs, VC_j, for each vessel group is defined as operating expenses less depreciation on vessel and less depreciation on fishing licenses and permits and less insurance on vessel (all of it as reported in the profitability survey). This value is divided by total catch to get average variable costs per kg for each vessel group (see Table A4 and A5) as we have no data on the distribution of costs within each vessel group. Hence, our optimal rent is lower than the one you would get if all vessels were replaced by the vessels with lowest variable costs.

The variable cost may be adjusted by a *time/catch relation* $f_{i,j}$ to take into account that the time used to catch fish of a certain species varies among species and vessel types. The f_{ij}-values applied in Steinshamn (2005) were based on estimates from the 1996 and 1994 Survey of Activities[10]. Steinshamn's (2005) numbers cannot be applied directly in our study because the Directorate of Fisheries later formed new and consolidated vessel categories. While Steinshamn (2005) operates with 25 vessel groups, we have as mentioned now 13 groups (see Table 4). Furthermore, the only existing *f*-values are based on 17-18 year old data when stocks and technologies were different. Thus for lack of better knowledge, we chose to set all $f_{i,j}=1$ if vessel group *j* catches species *i*, and otherwise, $f_{i,j}= 10$, a

[9] The reason is that the vessels included in the population have an income above a specific minimum level. This means that the number of vessels in the profitability survey are 1525, even if the Register of Norwegian Fishing vessels registers a total of 6250 in 2011 of which 5417 are active. Total catch in tons in the profitability survey is around 90 per cent of total Norwegian catch.

[10] In Norwegian: "Aktivitetsundersøkelsen i 1996".

large enough upscaling of the variable cost to prevent the vessel group from harvesting the particular species. It is possible that some vessel groups have f_{ij}-values lower/higher than one, in that case they might do more/less of the harvesting.

To estimate fixed costs FC_j we use data for total fixed assets for each vessel group from Directorate of Fisheries (2012). We deduct the book value of fishing licenses and permits from this value to get the value of fixed capital, and we add insurance on vessel (see Table A5).

We include by-catch constraints that show the relationship of haddock caught per unit cod (see Table A6). We also include restrictions on the length of the season due to weather conditions; climate, resource availability etc. (see Table A7). These are included in the model through an upward adjustment of the variable costs to get adjusted potential variable costs (see Table A8). Further, we introduce restrictions on the shrimp fisheries because it is unreasonable that coastal vessels with conventional gear 15-21 m' and 'coastal shrimp trawlers' would be able to increase their shrimp catches over what we have seen in the last three years by capturing market shares from ocean trawling vessels with cold storage plant (which are part of the trawlers on vessel group 6). Later in the sensitivity analysis we introduce further restrictions for other vessel groups.

Steinshamn (2005) also included a number of politically determined constraints on the distribution of fish catches among vessel groups; particularly coastal vessels versus ocean-going vessels. We do not include political constraints in our base case. The effect of political constraints is explored in the sensitivity analysis.

7. Optimization Results

Base case

In the base case, we add by-catch constraints, limit the number of vessels to the actual number of vessels in 2011 for each vessel group, and exclude politically determined catch distribution constraints among coastal and ocean-going vessels. Since the objective function is linear, the optimal solution will use the most profitable technology for each species up to the maximum capacity of that vessel group before employing another vessel group to harvest that particular species. We find the maximum resource rent for the base case in 2011 for the ten economically most important species using the

CONOPT optimization procedure in GAMS[11]. The profit maximizing resource rent from the ten economically most important species was found to increase by a factor of 4.55 from 2011-NOK 1.453 billion to 2011- NOK 6.614 billion. Add to this the resource rent of the species not included in this optimization (but included in the 2011 Profitability Survey), we get a total resource rent of NOK-2011 7.211 billion for commercial fishers and a resource rent of 2011-NOK 9.330 billion if the resource rent for these remaining species also could increase by a factor of 4.55 through efficiency improvements. Using these numbers and a discount rate of four per cent, the Norwegian fish resource is worth an estimated 2011-NOK 233 billion or 2014-NOK 245 billion (adjusted using the consumer price index).

We find that the optimal resource rent in 2011 is around 7 billion NOK more than the observed one. When decomposing the change in optimal resource rent compared to the actual rent into changes in total revenue and total costs, we find that total revenue falls by about 10 per cent, which means that the catches are actually redistributed to vessels that receive a lower price in the optimum. Simultaneously, total costs falls by around 80 per cent, this means that maximization of resource rent is almost synonymous with allocating the catch to the most cost-effective vessel groups. In 2010 and 2012 the average fish prices were lower. However, if we adjust total revenue and total costs for the national accounts numbers in 2010 and 2012 correspondingly (see Figure 1), we find that the optimal resource rent is 6.9 and 7.4 billion current NOK higher than the one observed in 2010 and 2012, respectively. Even if this is a very simple adjustment, these numbers are not far from the loss of 7 billion NOK in 2011.

Steinshamn (2005) calibrated a similar model with 2002 data that included ten species and also added some institutional constraints (i.e. the TAC distribution between coastal and ocean-going vessels). Steinshamn (2005) found that the resource rent could be increased from literally zero to 2002-NOK 7.365 billion that is 2011-NOK 9.2 billion[12]) with a five percent discount rate[13]. Steinshamn's and our resource rent estimates necessarily differ because of model calibration, different species included in the optimization model, different structuring of vessel groups, and because Steinshamn (2005) includes some additional institutional constrains. Our base case also includes a specific compensation to the owner of the vessel. In the base case, this compensation is set to the average mainland annual wages for non-resource sectors.

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[11] The GAMS code is available from the corresponding author upon request.

[12] Adjusted by the weighted average of the consumer price indices for public and private consumption.

[13] If running Steinshamns model with a four per cent discount rate the resource rent is 2002-NOK 7.921 billion.

Figure 4 shows the model results in terms of participating vessel groups and their catch (in 1000 tons). Since the marginal profit is positive for at least one vessel group for all species, the entire TAC is caught. The only exception is capelin fisheries, where the marginal income is negative for all vessel groups.[14] We emphasize that some vessel groups over the years have had more possibilities for efficiency improvements within the prevailing regulations than others. These vessel groups will thus come out with relatively lower costs than those who have had less opportunity to choose the technology and capacity that best suits the fisheries they participate in. We would also strongly emphasize that the distribution of catch among vessel groups is sensitive to the definition of vessel groups by the Directorate of Fisheries and the time/catch parameter. In our results the groups with the biggest vessels are favored. It is possible that some of the groups with smaller vessels may have a time/catch parameter that lowers their cost sufficiently to include them in the model solution. In that case the fish catch would be redistributed to vessel groups with lower costs and, other things being equal, the optimal resource rent would increase.

The most efficient vessel groups are coastal seine vessels < 11m' (gr. 9) and 'coastal seine vessels >21m' (gr. 11). All existing vessels in these vessel groups are utilized in the solution. In addition, gr. 3 'coastal conventional vessels 15-21m', gr. 4 'coastal conventional > 21 m', gr. 6 'trawlers', gr. 7 'coastal shrimp trawlers', gr. 10 'coastal seine 11-21m', gr. 12 'purse seines' and gr. 13 'pelagic trawlers' are used in the solution. Vessel groups 1, 2, 5 and 8 are not fishing in the optimal solution given our calibration of the data. These groups either receive too low prices for their fish or have too high costs.

'Coastal shrimp trawlers' catch shrimp up to capacity (4,950 ton), 'coastal conventional vessels 15-21m' catch 150 ton and 'trawlers' catch the remaining (4,950). 'Pelagic trawlers' catch all saithe up to capacity (176,031 ton). Haddock is caught by 'coastal seine vessels < 11m' (26,660 ton), 'coastal seine vessels 11-21 m' (14,918) and 'coastal seine vessels > 21m'(107,584). 'Coastal seine vessels > 21m' also catches all the cod (275,948 ton). 'Coastal conventional > 21 m' catches all the cusk (12,322 ton) and all the ling (14,431 ton). 'Purse seines' catches the whole herring quota (615,642 ton), the whole mackerel quota (199,501 ton) and all the blue whiting (18,323 ton). The purse seines are responsible for most of the catch; as much as 833,436 ton.

[14] Even if we double the length of the season and hence vessel capacity, which means a halving of the variable costs for all vessel groups, the capelin fisheries is still not profitable. The landed value of capelin was around 5 per cent of the total value of our ten species in 2011.

Figure 4. Model results, in terms of catch in 1000 tons for each vessel group and species.

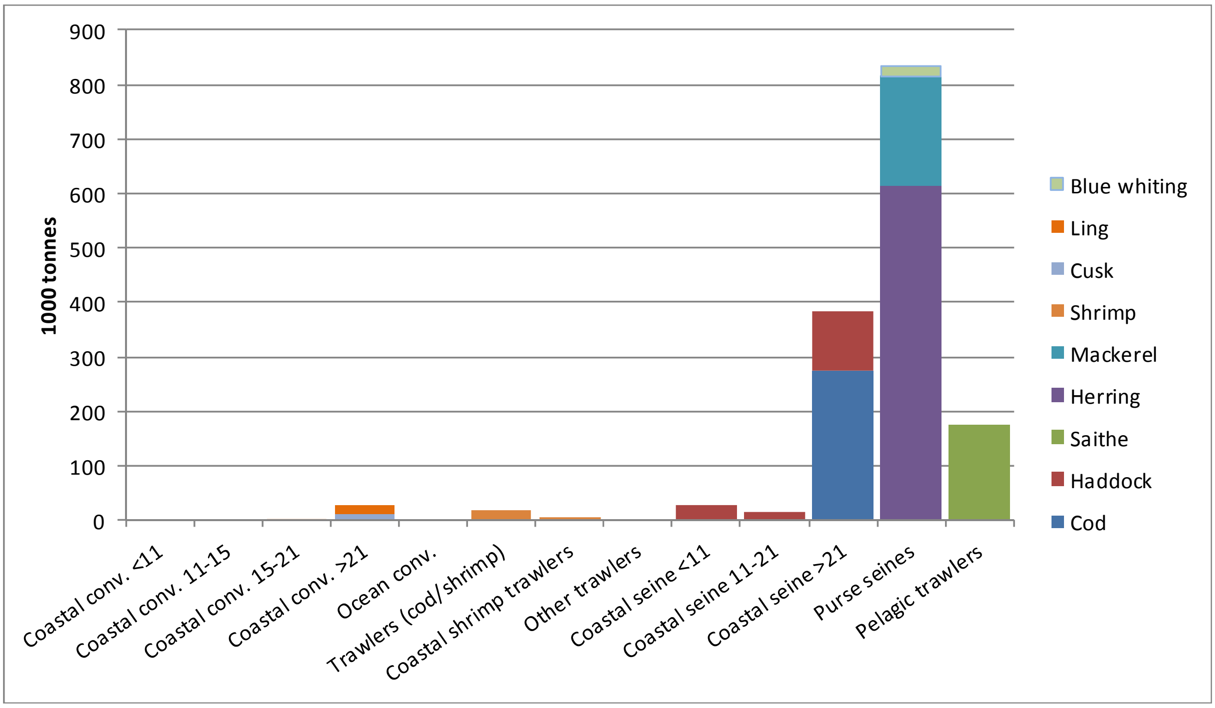

Figure 5. Optimal resource rent by vessel group and change in employees by vessel group.

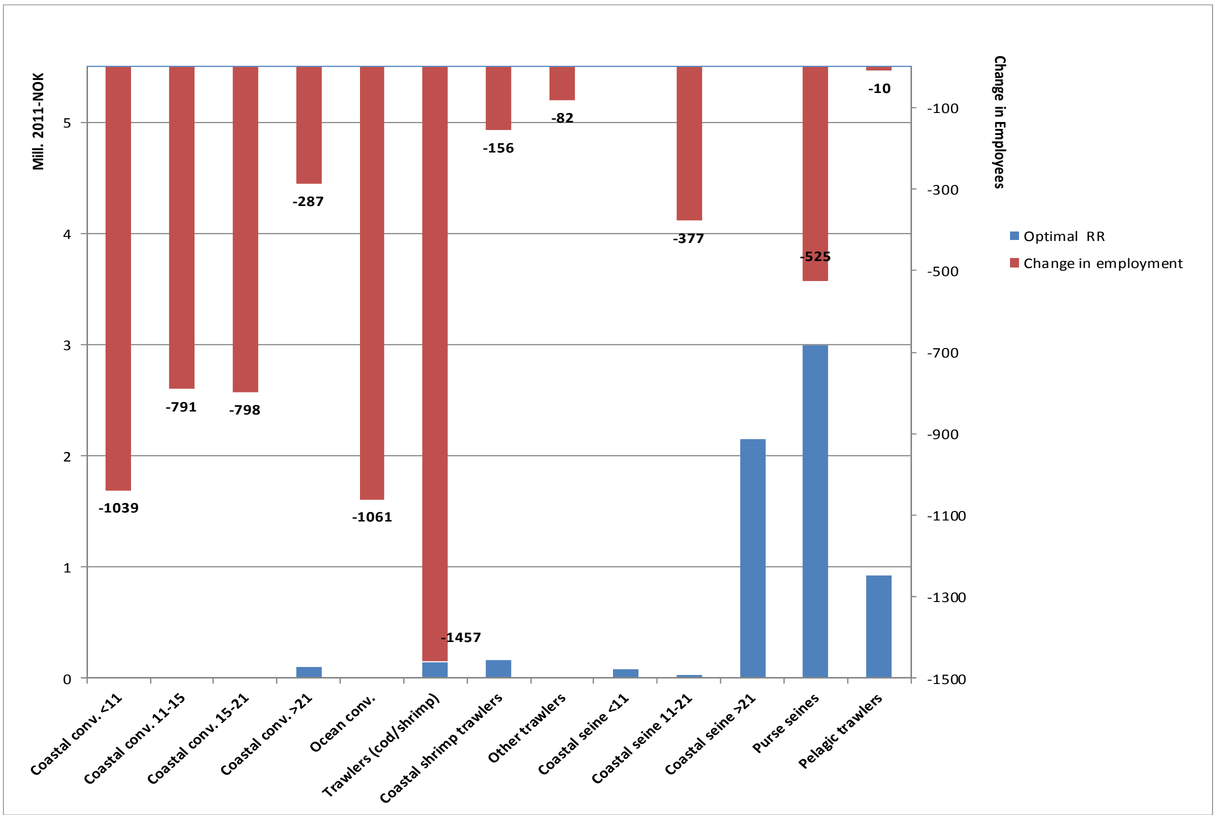

Figure 5 shows the distribution of the optimal resource rent among vessel groups in the base case. As measured in 2011-NOK, ‘purse seines’ have the largest resource rent of 2.99 billion, ‘pelagic trawlers’ have a resource rent of 926 mill, and ‘trawlers’ earn a surplus of 147 mill. The resource rent among coastal vessel groups is distributed as follows: ‘coastal shrimp trawlers’: 167 mill.,‘coastal seine vessels < 11m’: 86 mill., ‘coastal seine vessels 11-21m’: 29 mill., ‘coastal seine vessels > 21m’: 2.156 billion, ‘coastal conventional vessels 15-21m’: 5 mill., and ‘coastal conventional vessels >21 m’ 106 mill. Employment in fisheries is reduced from 8389 positions to 1,806 positions.

Optimal Resource Rent for the most Efficient Vessel Groups

Our results show that the resource rent could be much higher than what it is under the current conditions and policy regime. What the optimal resource rent could be is a hypothetical concept. The optimal resource rent critically depends on the assumptions we make for the use of labor and capital. The base case finds the optimal resource rent when using the existing vessel fleet more efficiently. The structure and efficiency of the current vessel fleet reflect past decisions and policies. What could the optimal resource rent have been if we had a more optimal (modernized) fleet of vessels? Recognizing that a new vessel fleet will not appear overnight, Steinshamn (2005) strategy to answer this question was to keep the existing fleet of vessels making each vessel as efficient as the most efficient vessel in the respective vessel group. To perform the analysis Steinshamn (2005) used data on costs from the Directorate of Fisheries. Because these cost data are not publicly available we were unable to repeat Steinshamn’s analysis for 2011 in the available time frame for this study. Instead we calculate the optimal resource rent if one freely could add new vessels to the most efficient vessel *groups* (types). We find that the resource rent for the ten economically most important species increases by 2011-NOK 108 mill to 2011-NOK 6.722 billion if one had unlimited access to vessels in the most efficient vessel groups. Hence it appears that building additional vessels of the most efficient types would only make a relatively modest contribution to increasing the resource rent.

The cost of politically distributing quotas among coastal and ocean-going vessels.

We also ran a case where we included politically determined constraints that divide the catch between coastal and ocean-going vessels. That is certain coastal vessel groups were not allowed to harvest more pelagic fish (herring and mackerel) than they did in 2011 and where certain ocean-going vessel groups were not allowed to harvest more cod than they did in 2011. Adding these constraints reduced the resource rent by an estimated 2011-NOK 952 mill.

8. Sensitivity analysis

Probably the most uncertain parameter in our analysis is the time/catch relationship for species *i* and vessel group *j*. Steinshamn (2005) based his f_{ij}-values on data from the 1996 activity analysis. Unfortunately, no new data on the time/catch relationship has been gathered since 1996. The accuracy of the f_{ij}-values is limited because they reflect the fish stocks, technology that was present in 1996. The accuracy of the former f_{ij}-values is further diminished by the fact that the official vessel groups in 1996 had been consolidated by 2002, and that there were further consolidations by 2011. We attempted to generate new f_{ij}-values but concluded that too many inaccuracies arose. Without further knowledge it is difficult to say what would be a meaningful sensitivity analysis for the f_{ij}-values. However, if we had the true f_{ij}-values, this would lead to reallocation of catch between vessel groups.

Another question for sensitivity analysis is how the optimal resource rent changes with other alternative wage rates of the fishers and the owners. In the base case we applied the average mainland wage rate for the non-natural resource industries for both fishers and owners, and it may be questioned whether this alternative wage rate is reasonable. The educational level is relatively low in the fishery sector, meaning that the base case may apply a too high alternative wage rate. Applying the annual average wage rate for the primary sectors[15] leads to a resource rent of NOK 7.282, a ten per cent increase from the base case. Following Steinshamn (2005), we set the alternative wage rate for the owners to zero. However, this only increases the resource rent with 2.5 per cent compared to the base case. The reason is that the number of owners compared to the number of fishers is relatively low in the vessel groups that have the highest profitability.

Further, we perform a sensitivity analysis on prices (+ / -) 20 per cent. Actually this price increase and decrease lead to a 36 per cent increase and a 37 per cent reduction in the resource rent, respectively. The reason is that the price changes alter the combined resource rent for 'purse seines' and 'pelagic trawlers' with as much as 80 per cent, and these groups constituted the lion's share of resource rent in the base case.

It may be unreasonable to assume that 'pelagic trawlers' can catch all saithe up to capacity (176,031 ton), as saithe is a groundfish. Hence, we run a sensitivity analysis where the pelagic trawlers were allowed to catch only half of the quota. This reduces the resource rent by only 3 per cent. The reason is that the other half of the quota now is caught primarily by 'purse seines' and to some extent 'coastal

[15] Applying the national accounts, the yearly wage rate in the primary sectors in 2011 was NOK 453,000 compared to a mainland wage rate of NOK 619,000. The latter was only one per cent lower than the average wage rate in the fishery sector.

seine vessels >21m', both groups being relatively cost-effective in the saithe fisheries, preventing a larger reduction in the resource rent.

We also study the effect on the results of the by-catch constraints between cod and haddock. Omitting the by-catch constrains has negligible effects on the results; the constraint is only binding for vessel gr. 4 'coastal conventional > 21 m' (see Table A6 in the appendix). The resource rent only increases with NOK 1 million, with a decline in the resource rent of vessel gr. 9 'coastal seine vessels >21m' of NOK 29 million, which is now not participating in the fisheries, and a corresponding increase in the resource rent of vessel gr. 4 'coastal conventional > 21 m' of NOK 30 million.

We also explore the effect of simply using the actual number of days in operation for each vessel group and not the potential number of days in estimating the resource rent. In other words, the fishing season for each vessel group is not increased and this means that vessels have constant capacity. We still take seasonal catch-limits into consideration if they are binding (see Table A7 in the appendix). The result is a reduction in the resource rent of 11 per cent from the base case.[16] The main explanation for this is a reduction in the value of the cod fisheries in 'coastal seine vessels >21m' (gr. 11) of almost NOK 700 million, although 'other trawlers' (gr. 8) increases its cod fishery somewhat. However, as 'coastal seine vessels >21m' is a group of large vessels, this result does not seem reasonable. Generally, larger vessels can exploit the fish stocks a larger part of the year than smaller vessels, i.e. they can increase their fishing season and capacity. However, all in all, the latter two sensitivity analysis show that the by-catch constraints and the assumption of increased seasonal length in the base case, is not important for our result; the resource rent can at least be increased by a factor of four from the present resource rent in 2011. The interest rate has been set to four per cent in all previous resource rent calculations at Statistics Norway, thus we will not run any sensitivity analysis on this parameter value.

9. Discussion of Results

The actual resource rent has generally been on an increasing trend from 1984 to 2014. Norwegian fisheries have in some of the later years had positive resource rent. However, in 2012-2014 the present resource rent were again negative. Factors contributing to the increasing resource rent over time are:

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[16] Even with the present seasonal length (as well as with the present vessel and gear types) this means that resource rent increases from NOK 1.453 billion in the base case to 5.874 billion, an increase by a factor of 4.

- A year by year reduction in the number of hrs. worked in the sector reducing total compensation to employees
- A reduction in the number of vessels thus reducing fixed costs and capital consumption, although the gross tonnage has remain fairly constant

Thus the actual resource rent in Norwegian fisheries has in large part been increased by reducing harvesting costs through fleet consolidation, which has led to less employment and lowered capital costs. Furthermore, the optimization results suggest that the resource rent in Norwegian fisheries could be greater than today. In principle, the resource rent could be increased through further reduction in the number of vessels and employment, by increasing the season length and by redistributing the catch to the vessels that receive the highest prices and have the lowest costs. Our results show that the single most important change in our optimization is allocating the catch to the most cost-effective vessel groups. We indicate that the resource rent could be increased by a factor of 4.5 from today's level. For the ten economically most important species the resource rent in 2011 could be, according to our results, increased from about 1.5 billion NOK to about 6.6 billion NOK. This order of magnitude increase in the resource rent of Norwegian fisheries is consistent with the results of previous studies. The optimal redistribution of catch among vessels depends on the calibration of the optimization model. The variable costs of each vessel group may be affected by time/catch relationships, for which we have no usable data. The last data on time/catch relationships were collected in a survey of fishers in 1996, when stock-levels and technology were quite different from today. Thus, while the resource rent could be increased considerably, we need better data on time/catch relationships to infer which vessel groups are the most efficient. With our calibration of the model, vessel groups that catch pelagic fish such as herring and mackerel are quite profitable, while coastal vessel groups appear less profitable, except for 'coastal seine vessels > 21m' which rank as the second most important vessel group after 'purse seines'. Finally, resource rents could hypothetically be even greater if TACs were set at the bioeconomic optimal level. TACs may be interpreted as maximum sustained yield (MSY). With improved technology for finding the fish and reduced search costs, MSY and bioeconomic optimal catch levels may not be all that different.

10. Conclusions and Further Work

We find that the actual resource rent of Norwegian fisheries has increased through fleet consolidation resulting in fewer employed and less capital costs. We also find that there is further potential for increasing the resource rent through further fleet consolidation, less employment, by allowing the most profitable vessels catch more and by extending the catch season. As the present resource rent can be increased by applying fewer fishers and fewer vessels, we are per definition in a situation of resource waste in the fishery sector as well as less value creation elsewhere as both human and fixed capital have an alternative value in other sectors. Furthermore, our results show that the dominating structural change needed is allocating the catch of the various species to the most cost-efficient vessels. We emphasize that some vessel groups over the years have had more possibilities for efficiency improvements within the prevailing regulations than others. These vessel groups will thus come out with relatively lower costs than those who have had less opportunity to choose the technology and capacity that best suits the fisheries they participate in. For our model calibration, we found that that the maximized resource rent in 2011 for the 10 most profitable species was about 6.6 billion NOK. If the same increase in the resource rent could be realized for all other species, the resource rent in 2011 for Norwegian fisheries could have been NOK 9.3 billion. Assuming that TACs were bioeconomically optimal, and for the prices and technology in 2011 this means that the Norwegian fish resource is worth NOK 230 billion.

Our sensitivity analyses show that it is highly probable that the optimal resource rent could increase further if we had applied lower alternative wages than in the base case, to better reflect the fishers and owners true alternative value. In addition, we show that our results of a potentially high optimal resource rent are neither dependent on assumptions of by-catch constraints nor on the extension of the actual fishing season nor capacity in 2011 for the various vessel groups. However, the resource rent is of course highly dependent on the prices, especially on those species caught by the most efficient vessel groups. We find that the optimal resource rent in 2011 is around 7 billion NOK more than the observed one. When decomposing the change in optimal resource rent compared to the actual rent into changes in total revenue and total costs, we find that total revenue falls by about 10 per cent. Simultaneously, total costs falls by around 80 per cent. In 2010 and 2012 the average fish prices were lower. However, if we adjust total revenue and total costs for the national accounts numbers in 2010 and 2012 correspondingly, we find that the optimal resource rent is 6.9 and 7.4 billion higher than the one observed in 2010 and 2012, respectively. Even if this is a very simple adjustment, these numbers are not far from the loss of 7 billion NOK in 2011.

The goal of this paper is not to suggest policy recommendations, but to make visible the cost of the present management system in the Norwegian fisheries. The Marine Resources Act emphasizes both settlement in coastal communities and efficient management of the resource. Some have argued that the ongoing rent dissipation only is a way to redistribute income in the fishery sector. However, as the resource rent can be increased by applying fewer fishers and fewer vessels, we are per definition in a situation with resource waste in the fishery sector as well as lower value creation in other sectors, as both the fishers and vessels have an alternative value in other industries. However, only in the unrealistic situation where the fishers and vessels that are removed from the fisheries in the optimal situation have zero alterative value in other sectors, the present management system could be described only as a way of financing employment in the fisheries through rent dissipation without leading to lower value creation in other industries as well.

The Marine Resources Act states that fish resources belong to Norway as a whole. The profitability of Norwegian fisheries has improved but is unequally distributed among vessel groups. The structural quota system has caused a consolidation in the fishing industry. In conjunction with the structural quota system the introduction of a tax on the resource rent was discussed in a government white paper (St.meld. 21, 2006). If such a tax is to be introduced much more would have to be known about the distribution of the resource rent in fisheries among vessel groups and owners.

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Appendix

Table A1. Catch of each species by vessel group (tons)

Vessel group	Cod	Capelin	Herring	Blue whiting	Haddock	Saithe
1	28878	0	0	0	6552	5331
2	35861	0	5120	0	10916	10701
3	34667	0	7125	0	15209	7598
4	17996	4142	17303	0	12546	8355
5	29948	0	0	0	27671	9549
6	103617	0	0	0	72496	67629
7	878	0	1769	0	0	3247
8	794	0	0	0	492	15188
9	630	0	5366	0	29	514
10	9483	8120	64298	0	1217	10942
11	12812	20117	118759	0	2034	34091
12	384	282731	338798	11119	0	1788
13	0	29518	57104	7204	0	1098

Vessel group	Cusk	Mackerel	Ling	Shrimp
1	0	0	0	0
2	0	3262	2174	0
3	1199	0	1233	150
4	812	0	1523	0
5	10311	0	8760	0
6	0	0	483	18870
7	0	535	0	4112
8	0	0	0	0
9	0	2428	0	0
10	0	10693	258	0
11	0	23722	0	0
12	0	145909	0	0
13	0	12952	0	0

Table A2 Average price of each species by vessel group 2011-NOK per kg

Vessel group	Cod	Capelin	Herring	Blue whiting	Haddock	Saithe
1	10.49	0	0	0	7.47	7.1
2	10.85	0	3.25	0	7.03	7.22
3	11.22	0	4.39	0	6.66	7.52
4	11.85	1.64	4.21	0	6.76	7.57
5	14.74	0	0	0	11.15	10.38
6	12.29	0	0	0	8.51	9.55
7	13.27	0	4.25	0	0	9.65
8	14.5	0	0	0	9.11	8.69
9	10.47	0	3.82	0	6.2	5.59
10	10.51	1.57	4.2	0	4.79	4.8
11	10.61	1.95	4.76	0	5.07	4.91
12	8.55	2.21	5.84	4.08	0	4.67
13	0	2.14	5.23	2.27	0	7.13

Vessel group	Cusk	Mackerel	Ling	Shrimp
1	0	0	0	0
2	0	8.95	7.6	0
3	7.77	0	9.78	38.15
4	6.99	0	10.22	0
5	8.86	0	13.49	0
6	0	0	9.73	16.7
7	0	9.64	0	51.78
8	0	0	0	0
9	0	9.33	0	0
10	0	10.39	6.61	0
11	0	12.09	0	0
12	0	12.98	0	0
13	0	10.57	0	0

Table A3. Capacity per vessel by vessel group

Vessel group	Number of vessels, all	Total catch per year in tons	Present capacity per year per vessel in tons	Days in operation per year	Potential number of days in operation	Potential capacity per year per vessel in tons
1	611	40761	67	173	330	127
2	293	65860	225	197	330	377
3	121	64749	535	200	330	883
4	37	56200	1519	207	330	2421
5	35	67168	1919	332	330	1908
6	39	262612	6734	305	330	7286
7	80	10541	132	214	330	203
8	4	16474	4119	300	330	4530
9	43	8967	209	111	330	620
10	93	96633	1039	182	330	1884
11	62	191418	3087	182	330	5598
12	80	486879	6086	173	330	11609
13	27	71154	2635	192	330	4529

Table A4. Variable costs (not adjusting for seasonal length) per kg

Vessel group	VC_i
1	18.16
2	11.03
3	8.67
4	6.35
5	10.44
6	7.93
7	25.08
8	7.08
9	8.32
10	4.61
11	3.91
12	3.23
13	2.36

Table A5. Insurance, fixed capital value and depreciation 2011-NOK

Vessel group	Insurance	Fixed capital value	Depreciation
1	24472	793740	67218
2	69796	1993793	175133
3	114469	4976681	378198
4	289408	17787350	1141719
5	467612	39170840	2308457
6	562586	64736886	5871420
7	75728	2301731	192430
8	328193	27377328	2817484
9	13980	774542	57965
10	142344	4127990	336927
11	348571	28331910	1595951
12	609190	66140942	4219244
13	323451	28136452	1994364

Table A6. By-catch of haddock per unit catch of cod in 2011

Vessel group	Lower limit (per cent)	Upper limit (per cent)
1	20	30
2	15	40
3	20	50
4	15	80
5	60	100
6	60	90

Table A7. Catch constraints

Vessel group	Catch constraint				
	Cod	Herring	Mackerel	Capelin	Blue whiting
1	2/3[17]				
2	2/3	1/2			
3	2/3	1/2			
4	2/3	1/2		1/3	
5	2/3				
6	2/3				
7					
8	2/3				
9	2/3	1/2	3/7		
10	2/3	1/2	3/7	1/3	
11	2/3	1/2	3/7	1/3	
12	2/3	1/2	3/7	1/3	2/3
13		1/2	3/7	1/3	2/3

[17] The season for cod is 330 days x 2/3 = 220 days. The potential capacity for vessel group 1 is 184 ton per vessel. This means that the adjusted potential capacity in the cod fisheries is scaled down with 2/3, i.e. 122.7 tons per vessel.

Table A8. Adjusted potential variable costs per kg[18]

Vessel group	Cod	Capelin	Herring	Blue whiting	Haddock	Saithe
1	14.28	25	25	25	9.52	9.52
2	9.89	25	13.18	25	6.59	6.59
3	7.89	25	10.52	25	5.26	5.26
4	6.14	11.94	7.96	25	3.98	3.98
5	16.02	25	25	25	10.68	10.68
6	11.10	25	25	25	7.33	7.33
7	16.58	25	16.26	25	16.26	16.26
8	9.66	25	25	25	6.44	6.44
9	4.20	25	5.6	25	2.8	2.8
10	3.81	7.62	5.08	25	2.54	2.54
11	3.24	6.48	4.32	25	2.16	2.16
12	2.55	5.10	3.40	2.55	1.70	1.70
13	25	4.11	2.74	2.06	25	1.37

Vessel group	Cusk	Mackerel	Ling	Shrimp
1	25	25	25	25
2	25	6.59	6.59	25
3	5.26	25	5.26	5.26
4	3.98	25	3.98	25
5	10.68	25	10.68	25
6	25	25	7.33	7.33
7	25	16.58	25	16.26
8	25	25	25	25
9	25	6.53	25	25
10	25	5.93	2.54	25
11	25	5.04	25	25
12	25	3.97	25	25
13	25	3.20	25	25

[18] Costs are set to 25 to prevent a vessel group from harvesting that particular species.

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