Value of Optimal Market-Oriented Harvest of Herring

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Contents

Abstract

The Norwegian herring industry has been growing significantly in the last decade. Both price and volume has increased. Although the growth of the industry is a result of both available resources and market demands, we find it is more driven by the significant world increasing demand for herring as food for people when the sustainability of world fishery resources become problematic.

The main objective of this paper is to identity the economic gains of adjusting herring harvest according to market demand. We want to find the level of the quota allocation in each season that would maximize economic value of the fixed quota in a given year. To address the research questions, two econometric models and one simulation model have been developed in this project.

The estimated results suggest, compared to January and February, that demand for the Norwegian herring are more elastic both at export level and fishermen level between September and December. In the recent years between 2006 and 2010, the demand levels are also higher between September and December. This indicates that more quotas should be allocated to the months between September and December. Currently, a large portion of quota is harvested between January and February when the herring is not at its best quality and highest value. The effect of this harvest pattern will be exacerbated if it continues as the quota is expected to be smaller over the next years.

By allocating quota optimally according to market demand, using the average yearly quota of 925 thousand tons between 2006 and 2010, fishermen revenue would be increased by 3.7%. The problem of market-oriented quota allocation becomes more important when the quota gets smaller. Our results suggest that when quota becomes 10% smaller in the next year, by allocating the quota optimally, fishermen's revenue only decreases by 1%. This result indicates that when facing reduction in quotas, the whole industry should think more about how to optimally use the available limited resources.

We also found that price adjustment to an external change is smaller for the trading companies (export level) compared to the fishermen. For example, when trade and landing volumes in January decrease by 1%, respectively, it will make the price in the trade level and fishermen level increase by 0.36% and 0.59%, respectively. It means when herring harvests increase, export prices decrease less compared to fishermen prices. The exporting companies

get an extra margin when the prices in the destination markets do not change in the same pace. It also means when herring harvests decrease, export prices increase less compared to fishermen prices. The exporting companies get a smaller margin when the prices in the destination markets do not increase correspondingly. Assuming that the quota gets smaller over the next years, compared to fishermen, trading companies are hurt more.

1 Research Objectives

Harvest pattern of the Norwegian-Spawn herring has changed over the last decades. In recent years, more herring has been harvested between January and February, a period when the herring quality is relatively poor and price is relative low. In this case, the harvest pattern did not provide an optimal value of a limited fish resource. A typical example is the herring harvest in 2010. A large portion of the quota was fished in January and February when the herring is not at its best quality and highest value. The price in the lowest period was almost half of that in the best. This problem will become even worse when the quota is expected to decline over the next years. Obviously if the herring harvest can be adjusted according to market demand, revenue and profit of the herring industry will be greatly improved.

The main objective of this paper is to identity the economic gains of adjusting herring harvest according to consumer preferences and demand. We want to find the level of the quota allocation in each season that would maximize economic value of a fixed quota in a given year. We would also suggest optimal allocation of the quota when the herring quota is reduced by 10% in the future.

2 Introduction of the Norwegian Herring Industry

To implement the research objective, we need to know the background of the Norwegian herring industry. The data issue should be clarified at the beginning of the analysis. Exports of herring are not specified as the Norwegian Spring-Spawn herring (NVG) or North Sea herring. They are labeled herring in general. We do not know what kind of herring is exported exactly. However, according to the harvest data and export data, some 85% of the herring exported from Norway is NVG herring. Furthermore, the harvest season of these two herring stock is quite differently. Based on this knowledge, we know that almost all herring is NVG herring. Unless noted as NVG herring, herring is hereafter referred to as herring in general.

Norwegian herring industry has been growing very fast over the last decades (Table 1). The harvest volume increased from 339 thousand tons to 924 thousand tons between 1988 and 2010. At the same time, export volume (converted to round fish equivalent weight, REW) increased from 158 thousand tons to 825 thousand tons. The peak year is 2009. The harvest and export volume are 1077 and 937 thousand tons, respectively.

Price formation in the market is based on supply and demand, the same principles applies for the herring industry. The growth of the Norwegian herring industry is based on the availability of herring resources and world demand for herring. However, it is probably more based on the latter. Herring used to have little value and was amongst many uses used as feed for aquaculture. When the sustainability of world fish resource became problematic and world demand for seafood has been significantly growing, demand for herring as food for people has been substantially increasing. Figure 1 indicates that the export price of the Norwegian herring is highly correlated with the growth of the world economy, not with the world CPI. It means that the increase of herring price is driven by the world demand, not the inflation rate. The year of 2000 is important (figure 2). After it, both the herring landings and export prices doubled.

Table 1 also shows that the export price of herring is growing associated with the increase of harvest and export volume. Without significant growth of the world demand, the increase of herring harvest will definitely cause the prices to decline. Based on the above analysis, therefore, we conclude that the growth of the Norwegian herring industry has been mainly explained by the world demand for herring.

Table 1 Norwegian Export and Harvest of Total Herring (thousand tons)						
Year	**Export**		**Harvest**		**Export/Harvest**	
	Volume	Price (NOK/kg)	Volume	Price (NOK/kg)	Volume	Price
1988	158	2.49	339	1.20	47%	207%
1989	187	2.53	275	1.41	68%	179%
1990	154	2.89	208	1.67	74%	173%
1991	188	2.88	201	1.79	94%	161%
1992	160	2.75	227	1.50	70%	184%
1993	268	2.44	355	1.33	76%	184%
1994	373	2.59	550	1.35	68%	191%
1995	497	2.67	687	1.43	72%	187%
1996	655	3.36	763	1.93	86%	175%
1997	727	3.28	923	1.71	79%	192%
1998	575	3.27	832	1.76	69%	186%
1999	618	2.99	829	1.45	75%	206%
2000	722	3.29	799	1.81	90%	182%
2001	588	5.79	580	3.94	101%	147%
2002	520	5.34	573	3.61	91%	148%
2003	528	4.19	563	2.55	94%	165%
2004	587	4.67	616	3.33	95%	140%
2005	644	5.63	748	3.90	86%	145%
2006	626	4.75	710	3.21	88%	148%
2007	787	4.15	885	2.56	89%	162%
2008	873	4.33	1030	2.77	85%	157%
2009	937	4.31	1077	2.52	87%	171%
2010	825	4.44	924	3.01	89%	148%

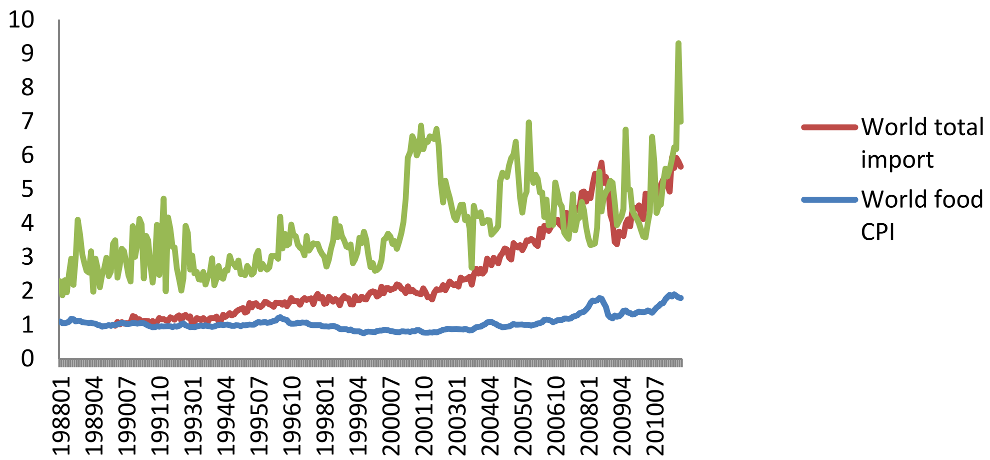

Figure 1 Export Price of Total Norwegian Herring and World Economy

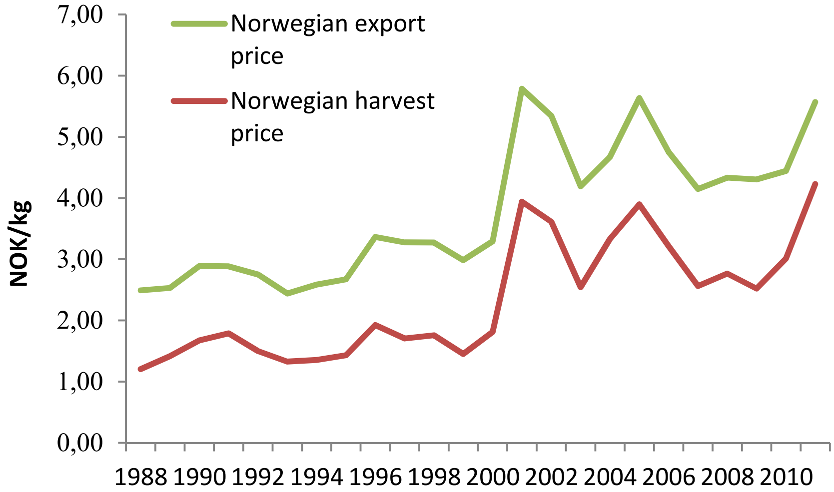

Figure 2 Prices of Norwegian Herring

2.1 Exports of the Norwegian Herring

Table 1 shows that the share of the Norwegian herring exported increased from 47% to 89% between 1988 and 2010[1]. We assume the exported herring are mainly used directly as or processed to food for people. The main import countries are Russia, Ukraine, Nigeria, Germany and Holland. They account for about 70% of the total Norwegian export (Table 2). Among them, Russia is the most important, accounting for 26% of total Norwegian export in volume. The imports of Holland are mainly North Sea Herring, which are used to produce Maatjesharing, a special product in Netherland.

Figure 3 presents the product forms of herring exported from Norway to the world. Both in value and quantity, export of frozen whole fish is dominant. It accounts for around 67% of total herring, followed by 16% of frozen butterflies cut, 8% of frozen fillet and 7% of fresh whole fish.

[1] The share larger than 100% is due to a measurement error of the converting rate from product weight to REW.

Figure 4 presented the monthly export and harvest of the Norwegian herring between January 2006 and July 2011. It suggests that the seasonal pattern of the export is quite consistent with that of the harvest. This suggests that the inventory behavior is negligible[2].

Table 2
Main Importers of Norwegian Herring

	Value shares	Quantity shares
Russia	0.254	0.264
Ukraine	0.128	0.135
Nigeria	0.121	0.177
Germany	0.102	0.070
Holland	0.067	0.039
Remaining countries	0.328	0.316

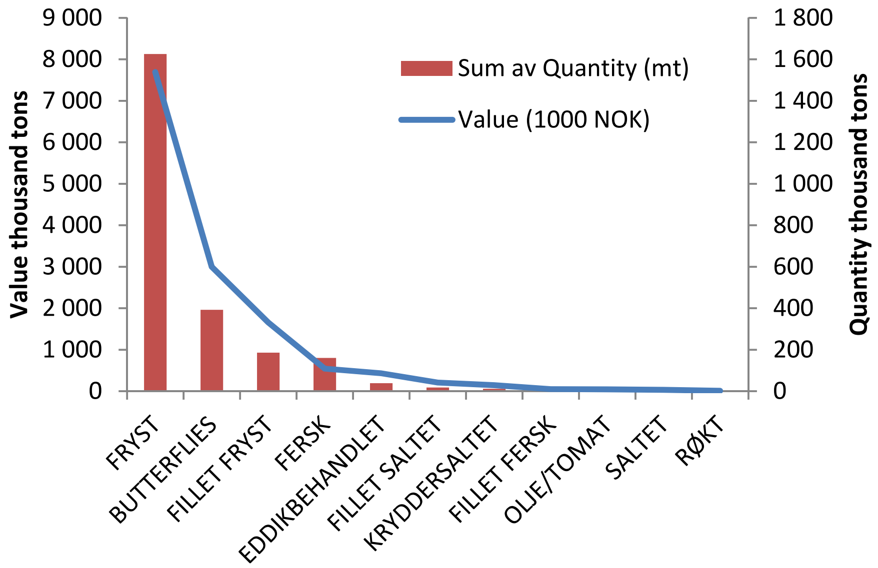

Figure 3 Export Product Forms of the Norwegian Herring (2008 -2011)

[2] However, storage is not an element in our economic analysis, due to unavailability of storage data.

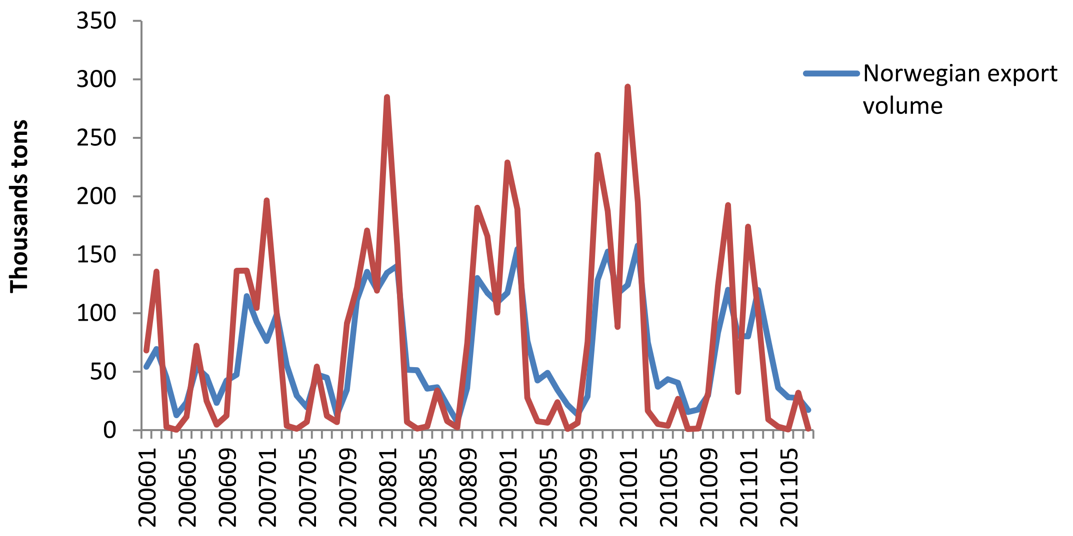

Figure 4 Exports and Harvests Volume of the Norwegian Herring

2.2 Exports of the Herring from the Other European Countries

Between 1994 and 2010, the total herring exported from Norway, Iceland, the Faroe Islands and Denmark increased from 557 thousand tons to 1155 thousand tons. Except for Denmark, the other countries significantly increased their exports. Among them, averagely per year, Norway, Denmark, Iceland and the Faroe Islands accounts for about 71%, 17%, 7% and 5% of the total herring exports (Table 3). As we discussed, the data on herring export herring does not represent the NVG herring exactly. It includes all stocks of herring. However, the share of the export from these countries/regions more or less reflects the quota allocation of the NVG herring.

According to the Agreed Record of Conclusions of Fisheries Consultations on the Management of the Norwegian Spring-Spawning (Atlanto-Scandian) Herring stock in the North-East Atlantic for 2011, signed between Norway, Iceland, Russia, the European Union (EU) and the Faroe Islands. The total NVG herring stock in 2011 is 988 thousand tons. It was shared 61% by Norway, 15% by Iceland, 13% by Russia, 7% by the European Union (EU) and 5% by the Faroe Islands.

No Russian trade or harvest data are available for this project. Since the EU is both an export and import region, it is imprecise to use the EU export as the world import from the EU. According to the catch data of the EU, Denmark is one of the main countries using the

EU herring quota, thus, we use the Danish data to approximately analyze the world demand for herring from the EU.

Figure 5 represented the export prices of Norway, Iceland, the Faroe Island and Denmark in US dollars. The Norwegian price is the next cheapest to the Faroe Island's price, close to the Icelandic price after 2000. The Icelandic price is highest between 1995 and 2000. However, after 2000, the Danish price is the highest. The margin of the Danish price with other exporting countries has been enlarged.

There exists a huge seasonal fluctuation in the export prices of all these countries (figure 5). In general, prices of the North Sea herring harvested during June and July is relatively higher than that of the NVG herring harvested between September and February the next year. The fluctuation of the price is partly explained by the stocks and quality of the fish, but at least partly explained by the demand level of the market between seasons. It would be beneficial to the herring industry and fishermen if they can allocate the volumes of export and catch according to the market level of the world market between months.

Table 3
Export of Herring from Main European Countries
(thousand tons in REW)

Year	Norway		Iceland		Faroe Islands		Denmark		Total	
	Volume	Share	Volume	Share	Volume	Share	Volume	Share	Volume	Share
1994	373	67%	33	6%	3	1%	149	27%	557	1
1995	497	69%	37	5%	29	4%	156	22%	719	1
1996	655	72%	48	5%	54	6%	149	16%	906	1
1997	727	73%	39	4%	88	9%	144	14%	997	1
1998	575	69%	22	3%	78	9%	153	18%	827	1
1999	618	74%	17	2%	43	5%	161	19%	839	1
2000	722	75%	28	3%	51	5%	161	17%	962	1
2001	588	70%	51	6%	34	4%	163	19%	836	1
2002	520	69%	52	7%	38	5%	148	19%	758	1
2003	528	70%	50	7%	23	3%	153	20%	753	1
2004	587	72%	70	9%	11	1%	145	18%	812	1
2005	644	67%	113	12%	32	3%	174	18%	964	1
2006	626	67%	112	12%	36	4%	165	18%	939	1
2007	787	73%	88	8%	46	4%	151	14%	1072	1
2008	873	71%	121	10%	66	5%	170	14%	1230	1
2009	937	74%	121	10%	67	5%	144	11%	1269	1
2010	825	71%	129	11%	73	6%	128	11%	1155	1
Average	-	71%	-	7%	-	5%	-	17%	-	-

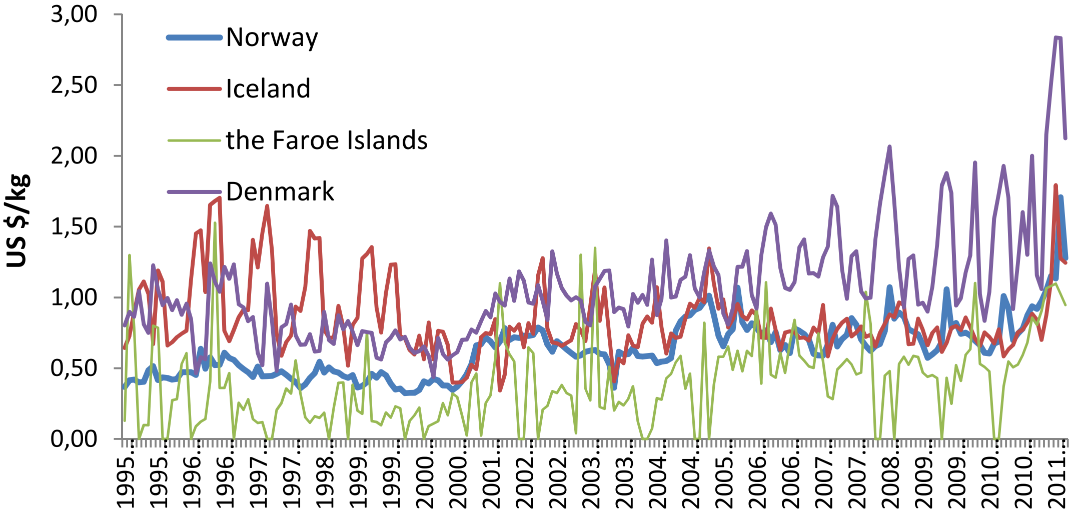

Figure 5 Export Prices of the Herring from the Main European Countries

2.3 Harvests of Norwegian Herring

Coinciding with the export growth, the catch of the herring has increased significantly in the last decade. The export of Norwegian herring, the total harvest of herring and the harvest of NVG herring present almost the same pattern in the whole sample period between 1988 and 2010 (figure 6). It confirms our earlier statement: based on the knowledge of total herring, we can get insight of the NVG herring.

Seasonal fluctuations in the catch pattern are the basis for our analysis in this project. Figure 6 shows that catch of the herring is very seasonal. It takes places mostly at the beginning and end of the year, and with a small peak in the early/middle of summer. Herring harvested at the beginning and end of the year is the NVG herring, which accounts for about 85% of the total Norwegian herring catches. The herring harvested in the early/middle of summer is the North Sea Herring. The NVG herring spawn in the period between March and

April. From September, the spawned herring fat up and maintain high quality. In January and February, herring quality is relatively lower when they are ready to spawn[3].

In a more detailed analysis, between 1994 and 2010, the average share of herring catch between January-February is 34%; September-November is 44%, March-August is 14% and December is 7% (table 4). This means that 86% of total herring was harvested between Septembers to February the next year. This is NVG herring. The remaining 14% of herring harvested between March-August is probably other species of herring, mainly North Sea herring.

Again from table 4, we can see that fishermen have been changing their fishing pattern in a year. During 94-96, they slightly harvested more NVG herring in January-February than in September-November (38% vs. 31%). However, after that, between 97-05, they harvested much less NVG herring in January-February than in September-November (28% vs. 50%). After 2005, although the fishermen still harvested less NVG herring in January-February than in September-November, the relative share in these two catch seasons are quite close (40% vs. 42%). Considering there are only 2 months between January-February but 3 months between September-November. The harvest in January-February is relatively more intensive after 2005. As we discussed, the quality of herring is higher in September-November compared to that in January-February. If the demand levels are the same between these two periods, the price should be lower as a joint result of more supply and lower quality.

To illustrate how the harvest price is determined by the supply and demand in the market. We took 3 examples in table 5. In 2000, relatively more herring are harvest in September-November than that in January-February. The price is also higher in September-November than that in January-February. This means that the demand level is higher in September-November than that in January-February. The higher demand level in September-November might be a result of high quality of herring. In 2002, harvest was double in October-November compared to that in January-February. Although the herring quality is much higher in October-November, the mass supply of the herring in a short time did drag the price lower. The price in October-November is at least ⅓ lower than that in January-February. In 2010, the harvest in October-November is ⅓ less than that in January-February. Both less harvest and higher quality make the prices in October-November much higher than that in January-February.

[3] However, the added value of roe in this period is not included in our analysis.

Based on the above three samples, we can see the mechanisms of market price determinations are complex. Herring with high quality does not necessary sell at a good price. Too intensive supply in a short time might drag prices down. On the other hand, although quality of herring is lower, if the demand level is higher or the supply is not as intensive at that time, price might be good. In general, the market price in a given month is determined by the demand level and the price elasticity in the specific month.

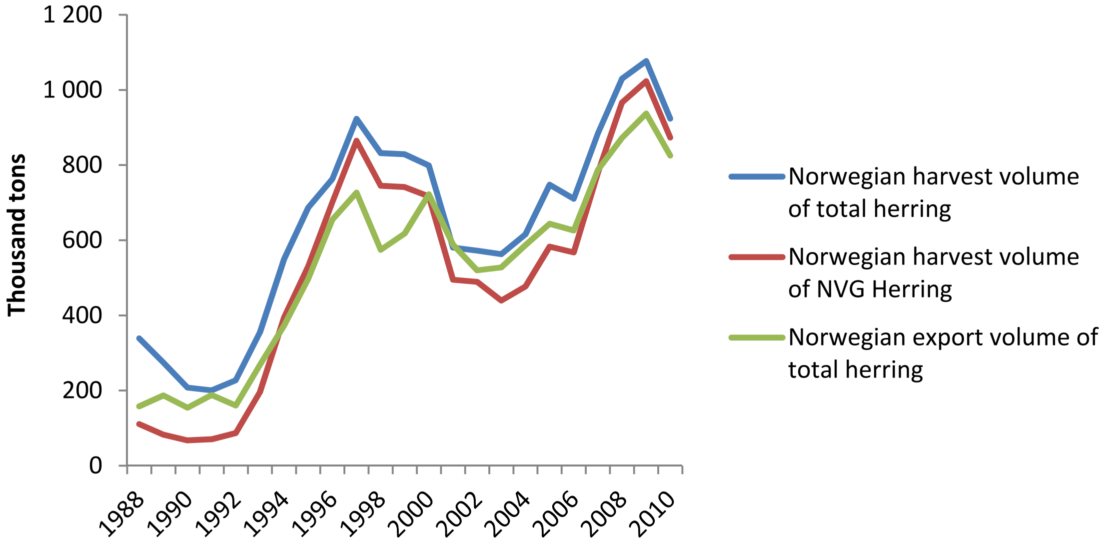

Figure 6 Harvests of Norwegian Herring

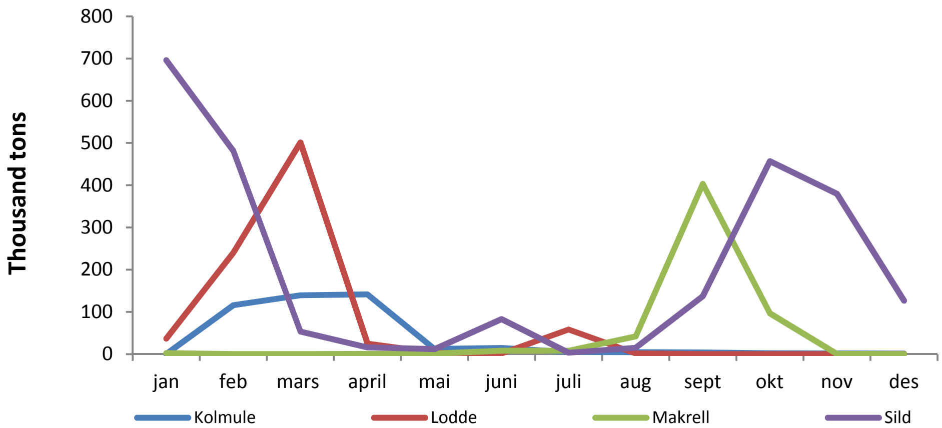

Figure 7 Harvest Seasons of the Main Norwegian Pelagic Fish

Table 4 Change of Catch Season between 1994-2010 (thousand tons in REW)									
Year	**January-February**		**Mar-Aug**		**September-November**		**Dec**		**Total**
	Volume	**Share**	**Volume**	**Share**	**Volume**	**Share**	**Volume**	**Share**	**Volume**
94-96	766	38%	508	25%	612	31%	113	6%	1999
97-05	1,839	28%	982	15%	3258	50%	382	6%	6462
06-10	1,849	40%	386	8%	1946	42%	445	10%	4626
Total	4,453	34%	1876	14%	5817	44%	941	7%	13088

Table 5 Seasonal Harvest Price of the Norwegian Herring (thousand tons)									
	2000			**2002**			**2010**		
	Volume	**Price**	**Value**	**Volume**	**Price**	**Value**	**Volume**	**Price**	**Value**
	thousand ton	**NOK /kg**	**million NOK**	**thousand ton**	**NOK /kg**	**million NOK**	**thousand ton**	**NOK /kg**	**million NOK**
Jan	130	1.28	166	79	4.36	347	294	2.23	655
Feb	102	1.47	150	97	5.16	500	195	2.17	423
Mar	16	1.75	28	16	5.03	78	17	1.90	31
Apr	2.0	1.58	3.2	0.7	2.58	1.8	5.3	2.48	13
May	15	2.08	31	22	3.11	69	3.8	3.86	15
Jun	38	2.04	78	30	3.20	97	27	5.08	136
Jul	17	2.04	35	6.6	2.90	19	1.0	4.12	4.0
Aug	11	2.01	22	0.6	2.13	1.3	1.3	2.25	3.0
Sep	116	1.87	217	22	3.42	76	32	3.02	95
Oct	136	1.73	235	168	3.08	519	124	3.53	436
Nov	165	2.22	366	102	2.78	282	192	4.31	830
Dec	50	2.29	115	28	2.77	78	33	4.29	140
Quota	798	1.81	1446	573	3.61	2069	924	3.01	2782

3 Research Methods

3.1 Seasonal Optimal Market-Oriented Quota Allocation Model

The main objective of this research is to maximize the value of a fixed quota. The fundamental rule to maximize the quota value is to shift quota allocation between the different seasons up to the point where the revenue obtained from the sale of the last unit in each season is equal. Or in other words, to get the optimal quota value, harvest in each season should be set to a level such that the last unit harvest in each month is equal. The problem of revenue optimization under the constraint of a fixed quota is mathematically solved in appendix A. A more straightforward understanding is depicted by figure 8 and 9.

One case discussed in appendix A is that the season with the greater level of demand gets the larger quota allocation. Figure 8 illustrate that the two seasons have the same demand slope, or in other words, consumers have the same quantity (price) sensitivity. The demand level (intercept of price axis) is higher in season 1 than that in season 2. With the same quantity supplied to each season, the price in season 1 is higher than that in season 2, which leads marginal value of the last unit of the quota is higher in season 1 than in season 2. To achieve the optimal quota value, more quotas will be shifted from season 2 to season 1. Season 1 gets a larger quota allocation in the end.

Another, more important, case discussed in appendix A is illustrated by figure 9. With the same amount of quantity added to the market in both seasons, price in season 1 declines more than in season 2, which suggests that the quota value will be higher if more catch are allocated to season 2. Therefore, season 2 should get relatively higher allocation of the quota compared to season 1. It is evident that the more quotas should be allocated to the season when both the demand level is higher and price is less sensitive to more supply.

The sensitivity of price with respect to quantity is measured by the price flexibility. Keeping other factors constant, more supply of a product will definitely make the price lower. Thus, the sign of the price flexibility is negative. Less price sensitivity means the absolute value of the price flexibility is smaller, and vice versa. The term price elasticity is more often used compared to the term price flexibility in economic analysis. Price elasticity measures how demanded quantity change with respect to price changes. By concept, price elasticity is the inverse of the price flexibility. Thus, less price sensitivity also means the absolute value of the price elasticity is bigger. Normally, we say that price is more elastic.

The focal point of this project is to identify the economic potential of the market-adjusted harvest of herring. To compute the gains, as indicated by equation (A11) in the appendix, we need to know the optimal levels of the prices and quota allocations in each month. To find the optimal prices and quota levels in each month, as illustrated by figure 8 and 9, also by equations (A7), (A8), (A1) and (A2), we need empirical estimates of the slopes and price intercepts of herring's month-to-month specific demand curves at the harvest level.

To understand the principal of the optimization problem, the above analysis is simplified to a two-season case. In the research, we want to find the optimal allocation for each month in a year, this more sophisticated optimal problem can be solved by first order condition (FOC) of a Lagrange function (A14) in the appendix A. Total quota in a year is optimal when an increase of quota amount does not increase total revenue. Therefore, the problem of how big a quota should be given, from a market perspective, in a whole year is solved by equation (A15).

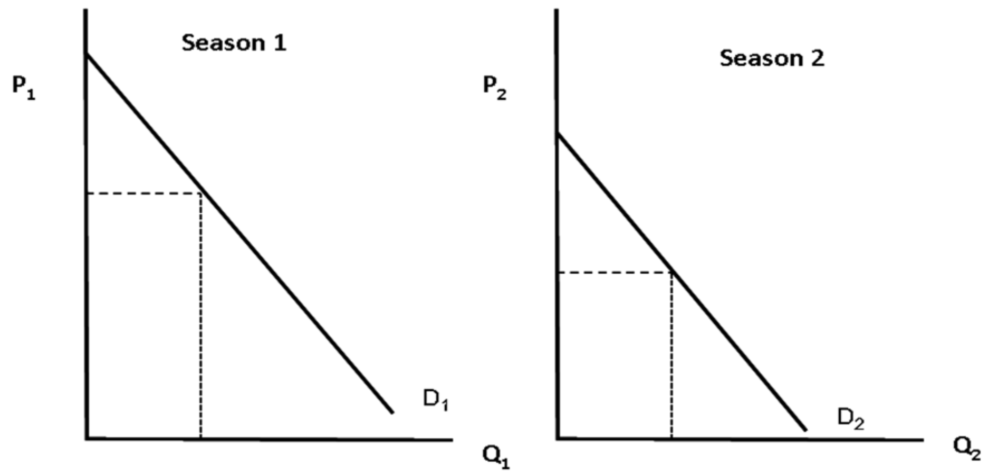

Figure 8 Optimal Seasonal Allocation of Quota under Different Demand Levels

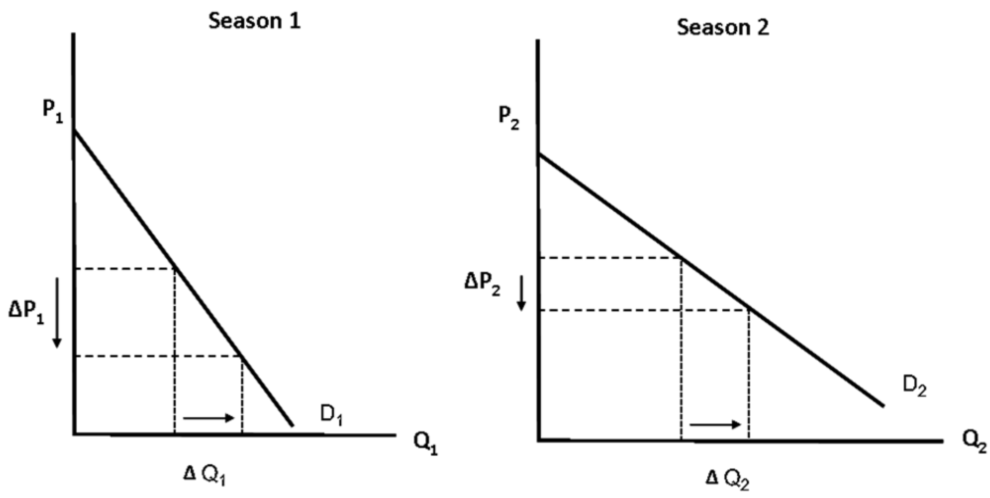

Figure 9 Optimal Seasonal Allocation of Quota under Different Quantity Sensitivity

3.2 Econometric Model to Estimate the World Demand Elasticities of Herring

Demand for herring at the harvest level is basically a derived demand from the trade level. Therefore, the first step of the project work is to get world import demand elasticity for Norwegian herring.

In the short run, when supplies are fixed, as in the case in a monthly model, the world demand elasticity for Norway's herring exports is proportional to the world demand elasticity, with the factor of proportionality equal to the inverse of Norway's trade share (see appendix B for the details). This factor is important because it simplifies the task of estimating the Norwegian demand elasticities needed in the monthly model. Since Norway's residual demand elasticity is proportional to the market demand elasticity, in computing the residual demand elasticity, it suffices to estimate the market demand curve. Estimates from that demand curve, coupled with average monthly values for Norway's trade share, can be inserted in equation (3) in appendix B to compute the monthly demand elasticities of the Norwegian herring at the trade level.

The inverse demand estimations have a long history in the study of fish price formation. Example includes Barten and Bettendorf (1989), Park, Thurman, and Easley (2004) and Xie, Kinnucan and Myrland (2008). Although most of the herring exports are frozen, according to figure 4 in section 2, inventory behavior is negligible at the herring export level. Therefore, quantities are treated as predetermined and inverse demand function was estimated instead of an ordinal demand function.

The empirical inverse demand model was specified as:

$$(1) \qquad \ln P_t = a + b\ln Q_t + c\ln PS_t + d\ln INC_t + \sum_{i=1}^{11} e_i D_i \ln Q_t + \sum_{i=1}^{11} f_i D_i + g\ln P_{t-1}$$

Where; $P = P_N^{S_N} P_I^{S_I} P_F^{S_F} P_D^{S_D}$, is the average world price of the European herring computed using the Stone index. In the index, P_N, P_I, P_F, P_D is the export price of Norway, Iceland, the Faroe Islands and Denmark in US dollars, respectively; s_N , s_I , s_F and s_D are market share for Norway, Iceland, the Faroe Islands and Denmark in values, respectively; Q is the total exports of herring from the named countries; PS is substitute price proxied as world CPI for food; INC is world income proxy as total world imports; D_i is a monthly dummy variable. Since it takes longer than one month for price to adjust, P_{t-1} , a lagged dependent variable is also incorporated. Regression estimates are found using monthly data for January 1995 through July 2011.

Monthly world price flexibilities are computed by $F_i = (b + e_i)/(1 - g)$, where i indexes month; 1, 2,…, 12, respectively. Since price elasticities are inverses of price flexibilities, they are computed by $e_i = 1/F_i$.

As discussed, in our monthly model where suppliers are fixed, the world demand elasticity for Norway's herring exports is proportional to the world demand elasticity. It is computed using equation (B3) in appendix B: $\eta_N^i = \frac{1}{k_N^i}\eta^i$, where η^i is the world demand elasticity in month i ; η_N^i is the world demand elasticity for Norway's herring export in month i ; k_N^i is Norway's trade share in quantity in month i .

3.3 Econometric Model to Estimate the Price-Transmission between Prices at Export Level and Fishermen Level.

George and King (1971) discussed that the price elasticity of a derived demand curve at the harvest level can be obtained from the knowledge of the price elasticity of a demand curve at the trade level. We estimate a price transmission model to get the relationship between harvest demand and trade demand. The empirical model is:

$$(2) \qquad \ln P_t = h + i \ln P_{NH} + j \ln P_{t-1}$$

Where $P = P_N^{S_N} P_I^{S_I} P_F^{S_F} P_D^{S_D}$, as defined earlier, is the average world price of the European herring computed using the Stone index; P_{NH} is Norway's harvest price of herring in US$ per kg[4]. For the same reason as in the demand model, P_{t-1} is also incorporated here. Since both harvest price and export price are endogenous, two stage least square estimation (2SLS) was implemented. The instrument variables used are exchange rates of currency of the exporting countries against US dollar. Specifically, they are exchange rates of Norwegian kroner (NOK), Icelandic kroner (ISK), Denmark kroner (DDK), and EURO with US dollar, respectively. Regression estimates using monthly data for February 1993 through July 2011. No interaction terms of $P_{NH} * D_i$ are included because they were not significant. It means that price transmission elasticities are the same between months.

Demand elasticities of Norwegian herring at fisherman's level are, computed as:

$$(3) \qquad \eta_{NF}^i = i/(1-j) * \eta_N^i$$

[4] Since herring in the trade data is named herring in general, not distinguished between NVG and North Sea Herring. To keep it consistent, P_{NH} used here is the average harvest price for the total herring.

4 Data and Research Procedures

Capia AS (http://capia.no) was responsible to collect all the data used in the research. Most of the data cover the period between January 1993 and July 2011. The data include trade data on quantity, fob value of Norway, Iceland, the Faroe Island and Denmark, monthly harvest data on quantity and value of Norway, world food CPI, world total imports, exchange rates of NOK, ISK, DDK and EURO with US dollars, respectively, and yearly quota of Norwegian herring. All the prices were imputed by dividing value by quantity. The sources where Capia AS collected the data are the Norwegian Fishery Director (Fiskeridirektoratet), Norwegian Raw Fish Sales Organization (Sildesalgslag), and the International Fiscal Statistic of IMF.

The research proceeded in five steps. First, we obtained the monthly demand elasticities for the whole European herring industry by estimating demand equation (1). Second, weighting the estimated elasticities by the inverse of the Norwegian quantity shares in the whole European industry ($\eta_N^i = \frac{1}{k_N^i}\eta^i$), we derived the Norwegian demand elasticities at trade level. Third, we obtained the the transmission elasticity of Norwegian trade price with respected to harvest price by estimating econometric model (2). Fourth, using equation (3), we got the Norwegian demand elasticities at the harvest level. Finally, the Norwegian demand elasticities at the harvest level were used to impute the slopes and demand levels in appendix A. Following the methods detailed in Appendix A, we obtained the optimal quota for each month in a year and the optimal quota for the whole year.

5 Research Results

Estimation results for the world demand elasticities are given in table 6. The R^2 is 0.88, showing the demand model (equation 1) has a good explanatory power. The *t*-ratios suggest that world food price has no effect on export herring price. On the contrary, as analyzed in section one, world economy is significantly important to export herring price. The estimated parameter of herring export price respected to world imports is 0.196. It means when world imports increase by 1%, demands for herring increase by 0.196%.

Flexibilities in table 6 measure how much prices decrease/increase with respected to a 1% increase/decrease of volume. As discussed in section four, elasticity is the inverse of the flexibility. Therefore, elasticity measures how much volume demanded increase/decrease with respected to a 1% decrease/increase in price. According to the analysis also in section four, more herring should be supplied to the market when the absolute value of the flexibility is smaller, or in other words, when the absolute value of the elasticity is bigger, which means demand is more elastic. The estimated world demand elasticities are then weighted by the inverses of the Norwegian quantity shares in the whole European industry to get the world demand elasticities for Norwegian herring (table 7).

The estimated price transmission elasticity (equation 2) is presented in table 8. The R^2 is 0.85, again showing the econometric model used for the estimation works well. The estimated price transmission elasticity is 0.615. It means when harvest price increases by 1%, export price increases by 0.615%, and vice versa. This result is reasonable. In the agricultural and fishery sector, farmers and fishermen are always more risky than exporters. Farmers and fishermen are normally working in small scale and greatly depend on the natural resources. However, exporters relatively have larger capacity to adjust their business. In the literature, price transmission elasticities between farm and trade level are close to the cost share of farm product input in the exported good. In our study, this number is 0.537. It is close to the estimated price transmission elasticity, 0.615.

By multiplying the Norwegian export demand elasticity with the price transmission elasticity, we get the the Norwegian demand elasticities at fishermen level (table 9). We found that demand elasticities at both export level and fishermen level are elastic. It means that both trading companies and fishermen can get higher revenue by exporting more herring.

However, it also means that if the herring quota is expected to be smaller over the next few years, both trading companies and fishermen get less revenue.

The absolute numbers of the demand elasticities are much bigger at the export level than at the fisherman level, which means that the exporting companies will probably get hurt more when the quota is less, as expected over the next years. The reason for this is because when the quota decreases by 1%, the price in the fishermen level will increase by a relatively higher percentage than that at the trade level. Or in other words, fishermen are more sensitive to the change of quota. Taking January as an example, the elasticities at the export level and fisherman level are -2.743 and -1.687, respectively. By taking the inverse of the elasticities, we get the flexibilities. They are -0.36 and -0.59 at trade level and fishermen level, respectively. It means that when trade and landing volumes in January decreases by 1%, respectively, prices at trade level and fishermen level increase by 0.36% and 0.59%, respectively.

Table 10 shows the descriptive data of herring harvest between 2006 and 2010. North Sea herring harvested during summer was more expensive than NVG herring harvested mainly from September to February next year. NVG herring harvested between September-December was more expensive than that harvested in January-February. It means demand level for NVG herring was higher in September-December than in January-February. Between 2006 and 2010, averaged over each year, 214 thousand tons of herring was harvested in January, much more than any month in the same year. Quality of herring in January-February is lower than that in September-December. Consistent with quality, prices are lower in January-February than in September-December. This yields that the revenue got from harvest of 214 thousand tons herring in January is much lower than the revenue got from that of 170 thousand tons herring in November. The numbers are 82.3 million US dollars versus 93.3 million US dollars. Similarly, the revenue given by harvest of 162 thousand tons herring in October is 83.4 million US dollar, 50% higher than that given by 155 thousand tons of herring in February. This simple descriptive analysis suggests that the harvest mode in the recent years is problematic. The limited herring resource does not get the optimal value. As indicated, more catch should be allocated to September-December than that to January-February.

Using the estimated elasticities at fishermen level, we simulated a suggested optimal catch of each month. We assume a yearly quota that is the average quota between 2006 and

2010, which is 925 thousand tons. Similarly, the actually catch of each month is the average catch of that specific month between 2006 and 2010.

The results are presented in table 11. The optimal numbers of each month in the table tell us how much herring should be exactly harvested in each month in order to get the maximum revenue of 925 thousand tons of quota. For example, the number in January means that with a fixed amount of 925 thousand tons quota in a year, we should catch 204.9 thousand tons of herring, instead of actual catch of 214.4 thousand tons. The results overall suggest that less NVG herring should be harvested between January and March. Instead, more herring should be harvested between September and December. This result is consistent with our earlier analysis. Since demand levels are higher and consumer demands are more elastic (or less price sensitive) between September and December, more quotas should be allocated to these months.

Table 12 shows the corresponding revenues in each month given by the optimal allocation of 925 thousand tons quota to each month. Summing up of the optimal revenues in each month, we get total revenue of 441.6 million US dollar in a year. This number is the maximum value that 925 thousand tons herring quota can get with the current demand schedule. Thus it is called the optimal revenue. It is 15.7 million US dollars higher than the actual revenue, or 3.7% increase of fishermen's revenue.

A 3.7% increase of fishermen's revenue is good, but not quite significant. However, the optimal problem becomes much more important when the quota is smaller. If we assume that the quota is 10% smaller in the next years, it means yearly quota decreases from 925 thousand tons to 833 thousand tons. The optimal numbers in table 13 tell us how much herring should be harvested in each month when the yearly quota is 833 thousand tons. The results suggest 181.1 and 117.4 thousand tons in January and February, which are 84% and 76% of the actual average catch in this two month between 2006 and 2010, respectively. However, a 10% reduction of quota seems to have a very slight effect on the harvested volumes between September and December. This means that when quota become smaller, the reduction amount of quota should be mainly deducted from the catches in January and February, catches between September and December should be kept almost at the same to the current level. More interesting, when quota is 10% smaller, the optimal revenue is 421.5 million US dollars (table 14), which is close to the 425.8 million US dollars given by the revenue of the current

925 quota a year. This means although the quota is reduced by 10%, by allocating the quota optimally, the revenue only decrease by 1%. This is significant.

Table 6
Estimated Parameters and World Demand Elasticities

Variable	Parameter Estimate	t-ratio	Price Flexibility	Implied Price Elasticity
Intercept	-0.795	-4.04		
ln Q (Dec)	-0.154	-5.46	-0.476	-2.10
Ln PS	0.018	0.39		
Ln INC	0.196	6.39		
$\ln(P_{t-1})$	0.677	16.31		
June	1.101	3.03		
ln Q x Jan	-0.005	-0.70	-0.492	-2.03
ln Q x Feb	-0.007	-0.88	-0.496	-2.01
Ln Q x Mar	-0.003	-0.37	-0.485	-2.06
Ln Q x Apr	-0.016	-1.36	-0.524	-1.91
Ln Q x May	-0.011	-1.10	-0.510	-1.96
Ln Q x June	-0.253	-2.95	-1.258	-0.79
Ln Q x July	-0.030	-3.00	-0.568	-1.76
Ln Q x Aug	-0.043	-4.09	-0.609	-1.64
Ln Q x Sept	-0.023	-2.59	-0.546	-1.83
Ln Q x Oct	0.007	0.90	-0.455	-2.20
Ln Q x Nov	0.002	0.26	-0.470	-2.13
R^2	0.876			
Adjusted R^2	0.866			
DW	1.915			
NOBs	222			

Note: NOBs is the number of the observations used in the estimation.

Table 7 Monthly Price Elasticities of Export Demand for Norwegian Herring			
Month	**World Demand Elasticity**	**Norway's Quantity Share (2006-10 Average)**	**Norway's Demand Elasticity**
Jan	-2.03	0.74	-2.743
Feb	-2.01	0.80	-2.513
Mar	-2.06	0.76	-2.711
Apr	-1.91	0.74	-2.581
May	-1.96	0.73	-2.685
June	-0.79	0.63	-1.254
July	-1.76	0.59	-2.983
Aug	-1.64	0.31	-5.290
Sept	-1.83	0.51	-3.588
Oct	-2.20	0.73	-3.014
Nov	-2.13	0.76	-2.803
Dec	-2.10	0.75	-2.800

Table 8 Estimated Results of 2SLS estimates of the Price Transmission model			
Variable	**Parameter Estimate**	**t-ratio**	**Price Transmission Elasticity**
Intercept	0.106	2.38	
$Ln(P_{FN})$	0.230	3.24	0.615
$ln(P_{t-1})$	0.626	6.87	
R^2	0.852		
Adjusted R^2	0.850		
DW	2.076		
NOBS	222		
Fisherman's Share of wholesale dollar (P_{FN} /P)	0.537		

Note: The instrument list is $ln(P_{t-1})$, ln(NOK), ln(ISK), ln(DDK), ln(EURO)

Table 9 Demand Elasticities for Norwegian Herring at Export and Fisherman Levels of Market			
Month	Fisherman-Export Price Transmission Elasticity	Demand Elasticity	
		Export Level	Fisherman Level
Jan	0.615	-2.743	-1.687
Feb	0.615	-2.513	-1.545
Mar	0.615	-2.711	-1.667
Apr	0.615	-2.581	-1.587
May	0.615	-2.685	-1.651
June	0.615	-1.254	-0.771
July	0.615	-2.983	-1.835
Aug	0.615	-5.290	-3.253
Sept	0.615	-3.588	-2.207
Oct	0.615	-3.014	-1.854
Nov	0.615	-2.803	-1.724
Dec	0.615	-2.800	-1.722

Table 10 Basic Data Used for the Simulation of the Optimal Quota Allocation			
	Average Price Received ($/kg)	Average Quantity Harvested (mil Kg)	Average Value of Harvest (mil US $)
Jan	0.41	214.4	82.3
Feb	0.37	155.3	56.1
Mar	0.32	11.5	3.30
Apr	0.45	3.20	1.30
May	0.66	6.40	3.70
June	0.61	42.2	24.1
July	0.51	9.50	4.70
Aug	0.39	4.40	1.70
Sep	0.50	57.1	29.9
Oct	0.52	161.6	83.4
Nov	0.54	170.6	93.3
Dec	0.51	89.1	41.9

Table 11 Norway's Optimal Monthly Harvest of Herring (Assuming the Annual Quota is 925 thousands MT)				
	Optimal	**Actual**	**Difference**	**Optimal/ Actual**
Jan	204.9	214.4	-9.50	96%
Feb	135.2	155.3	-20.1	87%
Mar	9.70	11.5	-1.80	84%
Apr	3.0	3.20	-0.10	96%
May	7.0	6.40	0.60	109%
June	32.3	42.2	-9.90	77%
July	10.2	9.50	0.70	107%
Aug	5.8	4.40	1.50	134%
Sept	67.4	57.1	10.3	118%
Oct	176.3	161.6	14.8	109%
Nov	180.8	170.6	10.3	106%
Dec	92.5	89.1	3.40	104%

Table 12 Gains of Norway's Optimal Monthly Harvest of Herring (Assuming the Annual Quota is 925 thousands MT)			
	Harvest Revenue (mil US$)		**REVENUE**
	Optimal	Actual	GAIN
Jan	86.8	82.3	4.6
Feb	53.5	56.1	-2.6
Mar	3.4	3.3	0.1
Apr	1.4	1.3	0.1
May	4.4	3.7	0.6
June	25.8	24.1	1.8
July	5.0	4.7	0.2
Aug	2.0	1.7	0.3
Sept	30.6	29.9	0.7
Oct	88.0	83.4	4.6
Nov	94.7	93.3	1.5
Dec	45.8	41.9	3.9
Total	441.6	425.8	15.7
			3.70%

Table 13 Norway's Optimal Monthly Harvest of Herring (Assuming the Annual Quota is 833 thousand MT)				
	Optimal	**Actual**	**Difference**	**Optimal/ Actual**
Jan	181.1	214.4	-33.3	84%
Feb	117.4	155.3	-37.9	76%
Mar	8.10	11.50	-3.40	70%
Apr	2.70	3.20	-0.40	87%
May	6.60	6.40	0.10	102%
June	30.9	42.2	-11.3	73%
July	9.20	9.50	-0.20	98%
Aug	4.90	4.40	0.50	111%
Sept	60.5	57.1	3.40	106%
Oct	160.9	161.6	-0.70	100%
Nov	166.2	170.6	-4.40	97%
Dec	84.2	89.1	-4.80	95%

Table 14 Gains of Norway's Optimal Monthly Harvest of Herring (Assuming the Annual Quota is 833 thousands MT)			
	Harvest Revenue (mil US$)		**REVENUE**
	Optimal	**Actual**	**GAIN**
Jan	81.7	82.3	-0.6
Feb	49.7	56.1	-6.5
Mar	3.1	3.3	-0.2
Apr	1.3	1.3	0.0
May	4.3	3.7	0.5
June	25.5	24.1	1.4
July	4.8	4.7	0.0
Aug	1.8	1.7	0.1
Sept	29.1	29.9	-0.8
Oct	84.6	83.4	1.2
Nov	91.5	93.3	-1.7
Dec	44.0	41.9	2.1
SUM:	421.5	425.8	-4.34
PERCENT GAIN:			-1%

6 Concluding Remarks and Discussion

This research project suggests that more quotas should be allocated to the seasons when the market demand levels are higher and consumers are less price sensitive to more added herring volume. We find that demand for the Norwegian herring are more elastic both at export level and fishermen level between September and December, compared to that between January and February. In the recent years between 2006 and 2010, the demand levels are also higher between September and December. These results indicate that more quotas should be allocated to the months between September and December. Since the quota in a year is fixed, the results also indicate that less of the quota should be allocated to the season between January and February.

The reasons why both the demand levels are higher and consumers are less price sensitive to the quantity between September and December are complex. It is partly explained by the higher quality of herring between September and December. It might also be related to the convention of herring consumption in the importing countries in special holidays, such as Christmas. Something we should keep in caution is that more allocation of quota between September and December does not mean we should harvest herring as much as possible between these months. As illustrated by the case of 2002 in table 5 of section two, too much supply in October and November dragged the prices in these two months much lower than that in January and February.

By allocating quota optimally, with the average yearly quota of 925 thousand tons between 2006 and 2010, fishermen's revenue can be increased by 3.7%. The problem of market-oriented becomes more important when the quota is smaller. Our results suggest that when quota is reduced by 10%, and by allocating quota optimally, fishermen's revenue only decreases by 1%. This result indicates that the industry and the fishermen should think more about how to optimally use the available limited resources. They could both gain from this.

As a byproduct of the research, we found that price adjustment to an external change is smaller in trading companies compared to fishermen. It means when herring harvests increase, export prices decrease less compared to fishermen prices. The exporting companies get an extra margin when the prices in the destination markets do not change in the same pace. It also means that when herring harvests decrease, export prices increase less compared to fishermen prices. The exporting companies get a smaller margin when the prices in the destination markets do not increase correspondingly. Suppose the quota gets smaller over the next years, compared to fishermen, trading companies are hurt more. A smaller quota makes the margins between prices at fisherman level and trade level to shrink.

In order to get a general picture of world demand, the current research does not consider the differences between the consumer markets. For example, since each market has its convention of consuming herring products, consumer behavior in the Russian and Nigeria markets might be quite different from each other. This research also does not consider the interests of the different fishing vessels and the possible reactions taken by the other herring exporting countries (e.g., Iceland and the Faroe Islands) when Norwegian fishermen adjust their harvest seasons. More detailed research can be definitely be explored.

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Appendix A

Optimal Seasonal Allocation of an Annual Production Quota

Assume the amount of fish that can be harvested from a particular fishery in a given year has been fixed at $\tilde{Q}$, hereafter "quota." Assume further that the fish can be harvested continuously throughout the year, and that fish harvested in each period are consumed in that period. At issue is how to allocate the quota over the year to maximize quota value.

The problem is solved using the equimarginal principle. To illustrate, assume the year can be divided into two discrete periods with differing demand conditions. Assume further the relationship between quantity demanded and price can be expressed adequately by a linear equation. The demand equations in inverse form are written as:

(A1) $P_1 = \alpha_1 - \beta_1 Q_1$ (Demand in season 1)

(A2) $P_2 = \alpha_2 - \beta_2 Q_2$ (Demand in season 2)

The *alpha* parameters in these equations indicate the level of demand in each season; the *beta* parameters indicate consumer sensitivity to price. Thus, if $\alpha_1 > \alpha_2$ demand in season 1 is greater than in season 2. Similarly, if $\beta_1 > \beta_2$ then consumers are more sensitive to quantity (less sensitive to price) in season 1 than in season 2.

The marginal revenue relation corresponding to a linear demand curve has the same price intercept as the demand curve, but falls twice as fast. The marginal revenue relations corresponding to equations (A1) and (A2) are:

(A3) $MR_1 = \alpha_1 - 2\beta_1 Q_1$ (Marginal revenue in season 1)

(A4) $MR_2 = \alpha_2 - 2\beta_2 Q_2$ (Marginal revenue in season 2)

Given equations (1) - (4), the problem is to find the levels of Q_1 and Q_2 that would maximize quota value given the constraint:

(A5) $Q_1 + Q_2 = \tilde{Q}$ (Quota constraint)

The problem is solved by applying the equimarginal principle, which states that harvest in each season should be set to a level such that the last unit harvested in season 1 adds the same amount to total quota value as the last unit harvested in season 2. This condition is satisfied when the following equation holds:

(A6) $$MR_1 = MR_2 \qquad \text{(Equilibrium)}$$

The optimal values for Q_1 and Q_2 are found by solving equations (A3) – (A6) simultaneously to yield:

(A7) $$\overline{Q}_1 = \frac{\alpha_1 - \alpha_2}{2(\beta_1 + \beta_2)} + \left(\frac{\beta_2}{\beta_1 + \beta_2}\right)\widetilde{Q} \qquad \text{(Optimal harvest in season 1)}$$

(A8) $$\overline{Q}_2 = \frac{\alpha_2 - \alpha_1}{2(\beta_1 + \beta_2)} + \left(\frac{\beta_1}{\beta_1 + \beta_2}\right)\widetilde{Q} \qquad \text{(Optimal harvest in season 2)}$$

Equations (A7) and (A8) show that the optimal harvest pattern depends on the slopes and price intercepts of the product's season-specific demand curves. If $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2$ equations (A7) and (A8) reduce to:

(A9) $$\overline{Q}_1 = \frac{1}{2}\widetilde{Q}$$

(A10) $$\overline{Q}_2 = \frac{1}{2}\widetilde{Q}$$

and the quota is split evenly between the seasons. In general, the season with the greater level of demand (the larger alpha), and the greater sensitivity to price (the smaller beta) gets the larger allocation.

The gain from following the optimal rule is computed from the following equation:

(A11) $$GAIN = \sum_{i=1}^{2} \overline{P}_i \overline{Q}_i - \sum_{i=1}^{2} P_i^A Q_i^A$$

Where, P_i^A and Q_i^A are actual price and quantity in season *i*. Given empirical estimates of the *alpha* and *beta* parameters, and knowledge of the annual quota, the optimal quantities for each season are computed from equations (A7) and (A8). These values are then inserted into equations (A1) and (A2) to get the corresponding optimal prices. The optimal prices and quantities are then inserted into equation (A11) along with observed prices and quantities to compute the revenue gain from following the optimal rule.

Taking partial derivative of equation (A7) and (A8) with respect to the total available quota ($\widetilde{Q}$), we get

$$\text{(A12)} \qquad \frac{\partial \overline{Q_1}}{\partial \widetilde{Q}} = \frac{\beta_2}{\beta_1 + \beta_2}, \quad \frac{\partial \overline{Q_2}}{\partial \widetilde{Q}} = \frac{\beta_1}{\beta_1 + \beta_2}.$$

Equation (A12) can be used to calculate the adjustment of the quota allocation between the seasons when the total available quota varies between years.

To understand the principal of maximization problem, the above analysis is simplified to only have two seasons. When there are 12 months in a year, we wan to find the optimal allocation for each month, this can be solved by the following first order condition (FOC) of a Lagrange function (A14). The amount of optimal total quota in a year can be solved by equation (A15), and also the optimal total amount of the quota in a year:

$$\text{(A13)} \qquad TR = \sum_{i=1}^{12} p_i q_i - \lambda(Q - \sum_{i=1}^{12} q_i)$$

$$\text{(A14)} \qquad \begin{cases} MR_1 = \dfrac{\partial TR}{\partial q_1} = a_1 - 2b_1 q_1 - \lambda = 0 \\ MR_2 = \dfrac{\partial TR}{\partial q_2} = a_2 - 2b_2 q_2 - \lambda = 0 \\ MR_{12} = \dfrac{\partial TR}{\partial q_{12}} = a_{12} - 2b_{12} q_{12} - \lambda = 0 \\ \dfrac{\partial TR}{\partial \lambda} = Q \qquad \vdots \end{cases}$$

$$\text{(A15)} \qquad \frac{\partial TR}{\partial Q} = \lambda = 0 \qquad \text{(Optimal quota in a year)}$$

Appendix B

A Note on the Demand Elasticities to be used in the Seasonal Allocation Model for Norway's Herring Harvests

The objective of this note is to show that in the short run where supplies are fixed, as is the case in a monthly model, the residual demand elasticity for Norway's herring exports is proportional to the market demand elasticity, with the factor of proportionality equal to the inverse of Norway's trade share. This fact is important because it simplifies the task of estimating the residual demand elasticity needed in the monthly model.

To see this, let the initial market equilibrium be defined as follows:

(B1) $$Q_N = Q^D - Q_O^S$$

Where, Q_N is Norway's exports of herring, Q^D is the market demand for herring from all supply sources (Norway, EU, Faroe Islands, Iceland, Russia, etc.), and Q_O^S is the market supply of herring from all sources except Norway. Taking the derivative of equation (1) with respect to price and converting the resulting expression to elasticities yields:

(B2) $$\eta_N = \frac{1}{k_N}\eta - \frac{k_O}{k_N}\varepsilon_O$$

In this equation $\eta_N = (\partial Q_N / \partial P)/(P/Q_N)$ is the residual demand elasticity for Norwegian herring, $\eta = (\partial Q^D / \partial P)/(P/Q^D)$ is the market demand elasticity for herring exports from all sources, $\varepsilon_O = (\partial Q_O^S / \partial P)/(P/Q_O^S)$ is the market supply elasticity for herring from all sources except Norway, $k_N = Q_N / Q^D$ is Norway's trade share, and $k_O = Q_O^S / Q^D$ is the trade share of Norway's international competitors.

On a month-to-month basis the supplies of herring to the world market are determined primarily by governmental restrictions on harvest levels, and the capital stock of the fishing industry. In other words, in the short run herring supplies are unresponsive to price. This means the supply elasticity in equation (2) can be ignored when computing the residual demand elasticity for Norwegian herring. Specifically, with the maintained hypothesis that buyers regard herring from alternative supply sources to be perfect substitutes, the residual demand elasticity facing Norway on a month-to-month basis is given by:

(B3) $$\eta_N^i = \frac{1}{k_N^i}\eta^i .$$

Where, the superscript "*i*" indexes the month. The residual demand elasticity in month *i* is proportional to the market demand elasticity in month *i*, with the factor of proportionality equal to the inverse of Norway's trade share in month *i*. In any given month, the demand curve faced by Norway in the international market becomes more elastic as its trade share gets smaller, a standard result in trade theory. If the market demand elasticity is invariant across months, the demand for Norway's exports becomes more elastic in months in which its trade share declines, and less elastic in months in which its trade share increases. Conversely, if Norway's trade share is invariant across months, the demand elasticity for Norway's exports varies directly with the market demand elasticity.

Since Norway's residual demand elasticity is proportional to the market demand elasticity, in computing the residual demand elasticity it suffices to estimate the market demand curve. Estimates from that demand curve, coupled with average monthly values for Norway's trade share, can be inserted in equation (3) to compute the monthly demand elasticities of Norwegian herring.

An advantage of this indirect approach to estimating the residual demand elasticity is that only one quantity variable is required in the demand equation. Also, supply shifters à la Goldberg and Knetter (1997) are not needed. These are important advantages when testing for season-specific intercepts and slopes, as multicollinearity is likely to be a problem even without additional variables to indicate supply shifts. In essence, the indirect approach proposed here justifies a simple demand relation like the one estimated by Cheng *et al*. (1991) for lobsters.

As a by product of the indirect approach, we will have the information needed to compute the optimal seasonal harvest for the industry as a whole. A comparison of the industry's optimal harvest rule with Norway's optimal rule would tell us whether the rules are reinforcing or offsetting. This, in turn, would shed light on whether optimizing behavior would attenuate or magnify seasonal price swings, which might be of interest to industry and policy makers alike.