Lauri Pietikäinen

Cod fishery of the European Union and Russia at the Baltic Sea – a game-theoretic analysis

University of Helsinki
Department of Economics and Management
Working Papers nro 30
Environmental Economics
Helsinki 2005
Cod fishery of the European Union and Russia at the Baltic Sea –

a game-theoretic analysis

This study has been carried out with financial support from the Commission of the European Communities, 6th Framework Programme Specific Targeted Research Project, contract no. SSP8-CT-2003-502516 “Operational Evaluation Tools for Fisheries Management Options - EFIMAS”. It does not necessarily reflect its views and in no way anticipates the Commission’s future policy in this area.

Lauri Pietikäinen
Department of economics and management
University of Helsinki
# 1. INTRODUCTION

**2. INTERNATIONAL FISHERY POLITICS AND THE BALTIC SEA**

2.1. The role of the United Nations

2.2. Fishery politics in the Baltic Sea

2.3. Negotiations concerning the cod fishery until year 2005

2.4. Negotiations concerning the cod fishery in year 2005

**3. GAME-THEORETIC ANALYSIS OF THE COD FISHERY AT THE BALTIC SEA**

3.1. Introduction

3.2. The basic model and sole owner

3.3. Impacts of the social discount rate

3.4. Impacts of the fishery costs

3.5. Discussion

**4. CONCLUSION**

**REFERENCES**

**APPENDIXES**
1. INTRODUCTION

Traditionally, common property natural resources have been exploited freely by anyone. Anyone have had the right to exploit the resource, and no one have had the right to deny somebody from the exploitation. The tragedy of the commons occurs, when everybody thinks just his/her own benefit and ignores the impact of his/her own behavior on the others. At that time the resource is used more than the social optimum requires, and the overuse could lead even to the extinction of the resource. (Hardin 1968.)

Especially the high sea areas have been common property, and in the 1800s their fish stocks were considered as inexhaustible. General opinion was that fishing could not have several consequences on the fish stocks. There were no fishing restrictions until 1900s. During the world wars the improvement in the fishing gear led to situation, where the concept of overfishing was introduced. (Gordon 1954, 126.) Nowadays fishing is regulated in many areas, and the international fishing agreements are thought to help the economic, social and biological problems caused by overfishing.

Concluding of an international agreement has not been easy. Disputes between the countries over fishing have sometimes led nearly to war. The United Nation’s Law of the Sea was hoped to solve the problems concerning property rights, but serious conflicts are still arising. The most serious conflicts occurred in 1972 between Iceland and United Kingdom and in 1995 between Canada and Spain. (Hanley et al. 1997, 319).

The fishery politics and agreements are well suitable for game-theoretic analysis because of many exploiters of the resource, poor defined property rights and externalities. Game theory was applied to international fishery politics first time in 1979 by Gordon Munro. Later on, the game-theoretic approach has been used in wide range of the exploitation of the fish stocks.

In this essay we examine the fishery politics in the Baltic Sea by means of game-theory. The Baltic Sea is due her characteristic very sensitive to pollution and overfishing. These problems have encouraged the coastal states to cooperate e.g. in the field of fishery and environmental politics. (Common fisheries policy... 2003.) However, the concluding of agreements in the Baltic Sea has been difficult. Different parties have had
very different opinions about the sustainable usage of marine resources. The fishery in the Baltic Sea has been close to laissez-faire, because no active intervention has been used to control the total effort in an international level. In practice, there has been open access situation in the Baltic Sea. (Hildén 1997, 210-214.)

Until the year 2004 the negotiations concerning fishery in the Baltic Sea have occurred multilaterally within the International Baltic Sea Fishery Commission (IBSFC). The political situation changed remarkably when the Baltic states and Poland joined the European Union. Hence the negotiations will occur bilateral between the European Union and Russia. The new situation makes the analysis about the fishery in the Baltic Sea very current. In this paper we study fishery of the European Union and Russia at the Baltic Sea by means of game-theory. We have a closer look on impacts of different fishing costs and social discount rate of the European Union and Russia to the fisheries policy. We mainly adapt the study by Munro (1979).

In chapter two we discuss international fishery politics and the character of the Baltic Sea. In chapter three we carry out the game-theoretic analysis of the fishery at the Baltic Sea. Finally, we present a conclusion in chapter four.

2. INTERNATIONAL FISHERY POLITICS AND THE BALTIC SEA

2.1. THE ROLE OF THE UNITED NATIONS

The United Nations Law of the Sea agreement came into operation in 1994. The agreement includes regulations about e.g. economic and commercial exploitation of the seas, scientific research and environmental protection. (United Nations Convention... 1996.)

The Law of the Sea describes also the Exclusive Economic Zone (EEZ). EEZ covers 200 nautical miles from the state’s coastline to the sea. Within EEZ the coastline state has sovereign rights for exploiting and managing its natural resources. The coastline state has for example right to determine Total Allowable Catch Quotas (TACs) and determine whether other countries are allowed to fish in the EEZ. More than 90% of
the world fish catch is caught within the EEZs. It was largely hoped that the EEZs will solve all problems due to poorly defined property rights. (Bjørndal et al. 2000, 184).

Regardless of the EEZs, the fish resources migrate or extend over the national boundaries. Because of these troubles the administrative problems have not disappeared; the property rights were still poorly defined. Transboundary fish resources migrate in the EEZs and the adjacent high seas. These stocks are often referred also as straddling stocks. The management of the straddling stocks gained little attention until the turn of the 1980s and 1990s. It was until then when the international community realized that many of these straddling stocks were severely overfished. (Kaitala & Munro 1993.) In the new United Nations Law of the Sea agreement of 1995 states that the management of the straddling and highly migratory fish stocks should be managed by regional fisheries management organizations. (Bjørndal et al. 2000, 183).

The international fishery policy is also in the agenda of The Food and Agriculture Organization of the United Nations (FAO). FAOs goal is to promote e.g. sustainable development and food safety. (FAO Fisheries Department 2004.) FAOs Code of Conduct for Responsible Fisheries determines the principles of protecting, management and improvement of renewable marine resources. The Code was adopted in 1995 and it came into operation 1999. The implementation of the Code is voluntary. (Code of Conduct for Responsible Fisheries 1999.)

The regional fisheries management organisations can be found at many areas. Their goal is to promote common development and environmental protection. In addition, the RFMOs often offer advice on TACs and proper measures for environmental protection. Many RFMOs have different committees for these tasks. Some of the RFMOs are fully independent, but many of work in subordination of the FAO.

2.2. Fishery politics in the Baltic Sea

The Baltic Sea is completely under the jurisdiction of coastal states, and so most important fish stocks are shared between the countries bordering it. (Aps 2004, 190.) A
great majority of the Baltic Sea belongs to the EEZs of the countries who are members of the European Union. Only 5.8% of the Baltic Sea belong to the Russian EEZ.

The negotiations concerning the fishery at the Baltic Sea occur within IBSFC. IBSFC defines annually the TACs for the four main species (cod, salmon, herring and sprat) and divide the TACs for its members. IBSFC decisions are grounded on research and the advice of the International Council for the Exploration of the Sea (ICES). IBSFC also gives recommendations about fishery regulations, fishing zones and fishing periods. (IBSFC Homepage 2004.) In spite of the scientific advice, in most years the IBSFC’s TACs have exceeded the ICES recommendations. (Radtke 2003, 1114).

IBSFC co-operates with other international organizations. The delegates of ICES, HELCOM, FAO and The North-East Atlantic Fisheries Commission (NEAFC) often participate in IBSFC meetings as observers. IBSFC rules allows also observers from NGOs to participate in its meetings. IBSFC informs FAOs Committee on Fisheries (COFI) about its work every second year. (IBSFC Homepage 2004.) IBSFC is also a participant in Agenda 21 for the Baltic Sea Region. (Baltic 21… 2004.)

The thirtieth IBSFC session was held in Gdansk in September 2004. The session was first after the Baltic States and Poland joined the European Union. These countries announced at session that they will withdraw from the convention. As a consequence of the EU enlargement, IBSFC will close down in near future. According to the EU, the coming role of IBSFC as a bilateral commission for the EU and Russia is not practical, and IBSFC can be close down. Russia instead would have maintain IBSFC. (IBSFC Homepage 2004; External relations/Enlargement 2004.)

2.3. NEGOTIATIONS CONCERNING THE COD FISHERY UNTIL YEAR 2005

Until year 1977 the negotiations concerning the cod fishery in the Baltic Sea occurred bilateral within the coastal countries. The situation changed that time, when IBSFC was founded and negotiations turned multilateral. TACs set by IBSFC were exceeded in many years. The TAC system rejected in year 1982, and open access fishery lasted until year 1988. Since then TACs have been set, but countries have been unable to comply
with the rules. The situation could be considered as *de facto* open access. (Kronbak 2002, 24.) The usage of TACs has not been successful; the data about the fish catches has been distorted in large-scale. According to ICES estimates, real catches have been approximately 35 – 40% higher than reported catches. (ICES 2004.)

Before the Baltic States and Poland joined the European Union, EU pushed through a prohibition of the cod fishery at the Baltic Sea. Due to the resistance of Russia and Poland the plan did not come into force. (Kautsky 2003, 173.) The European Union could be seen more committed to the protection of the cod stock than Russia, Poland and the Baltic States. All parties have admitted the importance of the protection of the fish stocks, but efficient measures have not been carried out.

### 2.4. Negotiations Concerning the Cod Fishery in Year 2005

ICES recommended prohibition of the cod fishery at eastern and western Baltic Sea alike. According to ICES, the prohibition should be carried out until clear signs have been caught that the stock is recovered. (ICES 2004).

After ICES meeting IBSFC negotiated about the TACs for year 2005. The delegation of the European Union proposed TAC of 24 700 tons for the western Baltic cod which would be allocated wholly to EU. For the eastern Baltic cod the EU delegation was not able to propose TAC, because of uncertain scientific information. The Russian delegation did not accept the proposal of EU, and it’s proposal was as follows: TAC for the whole Baltic Sea 70 000 tons, of which for the western Baltic Sea 24 700 tons and for the eastern Baltic Sea 45 300. Including both areas, the share of EU would be 66 500 tons and the Russian share 3 500 tons. (IBSFC Homepage. 2004.) The Russian share would be 5% of the total catch, which equals the Russian EEZ area at the Baltic Sea. For the western Baltic Sea the Russian 5% share would be 1 235 tons and for the eastern Baltic Sea 2 265 tons.

IBSFC did not follow recommendation of ICES, but announced TAC of 24 700 for the western Baltic cod, which is wholly for the EU. For the eastern Baltic cod IBSFC was unable to announce TAC. Both parties agreed to restrict the fishery so that the catch in
year 2005 will not exceed catch in previous year. Then EU catch was 71 250 tons and Russian catch 3 750 tons. Russia and EU are continuing the work to achieve an agreement. In spite of the weak results, the co-operation of EU and Russia was described to been excellent. (IBSFC Homepage. 2004.)

Following the IBSFC meeting at December 2004, the European Commission decided to continue the cod fishery at the Baltic Sea. The decision was divergent with ICES recommendation, but was equal with the results at IBSFC. The European Commission reduced TAC by 16,55% to 24 700 tons for the western Baltic cod and 25,28% to 31 120 tons for the eastern Baltic cod. (TACs for 2004... 2004.) The total TAC for EU is 55 820 tons, which is much less than the year 2004 catch 71 250 tons.

The European Commission’s reasons for differing ICES recommendations were the stabilization of the TAC system and additional measures. The Commission believes that long-term approach and the stabilization of TACs will lead to sustainable use of fish stocks. (2005 fish quotas… 2004.) The additional measures means for cod means three areas in the southern Baltic Sea that are closed from fishery and some periods when fishery is prohibited. (Outcome of the Agriculture… 2004).

Because of the IBSFC abolition the negotiations will be bilateral between EU and Russia. The theoretical frame for the analysis of this new situation is two player game-theory and theory of shared fisheries.

3. GAME-THEORETIC ANALYSIS OF THE COD FISHERY AT THE BALTIC SEA

3.1. INTRODUCTION

We examine how different social rate of discounts and fishery costs affects to the cod fishery of the European Union and Russia. In this study we exclude the impacts of differences in the fishing fleets. This is reasonable, because the fishing fleet of EU is not homogenous: EU has coastal trawlers, pelagic trawlers and gillnetters. We also exclude
the differences in the consumer preferences: we assume cod is a valued catch both in EU and in Russia.

The model we use is based on the study by Munro (1979), where he examines the management of a resource jointly owned by two states. Munro´s model is very suitable for applying in the cod fishery of EU and Russia. We assume that the fisheries management policy is managed by single manager in both EU and Russia. The aim of this manager is to maximize his/her country´s benefits from the fishery.

3.2. THE BASIC MODEL AND SOLE OWNER

We use the Schaefer (1957) model to present the biological part: the population dynamics are modelled as follows:

\[ \frac{dx}{dt} = F(x) - h(t), \]

where \( h(t) \) and \( x(t) \) denotes harvest rate and population biomass at time \( t \) and \( F(x) \) denotes the natural growth function. In the Schaefer model,

\[ F(x) = rx(1 - x/K), \]

where \( K \) denotes the maximum biomass size and \( r \) (constant) denotes the intrinsic growth rate, and

[3.1] \( h(t) = qE(t)x(t) \)

is the harvest production function, where \( E(t) \) denotes the rate of fishing effort at time \( t \) and \( q \) (constant) is the catchability coefficient.

The harvest production functions, fishing efforts and social discount rates between EU and Russia are assumed to be identical. Besides we assume that demand for fish and the effort input supply functions are infinitely elastic. As the parties cooperate, we can think that we have the sole owner case.
The optimization model could then be denoted by:

\[
PV = \int_0^\infty e^{-\delta t} \left[ p - c(x) \right] h(t) \, dt,
\]

s.t.

\[
dx/dt = F(x) - h(t),
\]

\[
0 \leq h(t) \leq h_{\text{max}} \quad \text{and}
\]

\[
0 \leq x(t),
\]

where \( \delta \) denotes the instantaneous social rate of discount, \( p \) denotes the price of fish, \( h_{\text{max}} \) is the maximum feasible harvest rate and \( c(x) \) is the unit cost of harvesting.

c(x) is derived as follows: the total cost of fishing effort is \( C(E) \).

Besides it is assumed that \( C(E) = aE \), where \( a \) (constant) denotes the unit cost of fishing effort. From the equation [3.1] we see that

\[
E = h / qx.
\]

The total harvesting costs thus are

\[
C(x, h) = ah / qx
\]

and unit harvesting costs

\[
c(x) = a / qx.
\]

The optimization problem can now be seen as a linear optimal control problem, where \( x(t) \) is the state variable and \( h(t) \) is the control variable. The Hamiltonian for the problem can be stated
\[ H = e^{-\delta} \left\{ p - c(x) \right) h(t) \right\} + \lambda (F(x) - h(t)), \]

where \( \lambda \) is the shadow price of the resource discounted at time \( t = 0 \). The golden rule can be derived from the Hamiltonian\(^1\):

\[
F'(x^*) - \frac{c'(x^*)F(x^*)}{p - c(x^*)} = \delta.
\]

According to Munro (1979, 358), the golden rule shows “that the optimal biomass level is that level at which the own rate of interest of the resource is equal to the social rate of discount”. The equilibrium solution is not a function of time and it is not unique. Therefore the equilibrium harvest policy when \( x(t) = x^* \) is

\[
h^*(t) = F(x^*).
\]

Fishing is sustainable at that point, because only the growth of the stock is harvested. The model linear in the control variable \( h \) with regard to the optimal approach path \( x^* \). Therefore the optimal approach is bang-bang approach:

\[
h^*(t) = \begin{cases} h_{\text{max}} & \text{whenever } x(t) > x^* \\ h_{\text{min}} & \text{whenever } x(t) < x^* \end{cases}
\]

3.3. IMPACTS OF THE SOCIAL DISCOUNT RATE

The social discount rate means the value that decision-makers have given to the benefits or costs appearing in the future. In fisheries management this means the valuation of future benefits from the fishery. If the manager values the future benefits highly or wants to protect the fish stocks, the social discount rate is low.

It is assumed that the European Union has lower social discount rate than Russia. The assumption is supported by EU’s greater eagerness to protect the cod stock in the Baltic

\(^1\) To derive the golden rule from the Hamiltonian, see appendix 2.
Sea: in the negotiations concerning fishery for 2005 the European Commission decided to limit the catches to 55,820 tons in the whole Baltic Sea, which is much lesser than the proposal Russia made in IBSFC (70,000 tons). Earlier EU has even required the prohibition of the cod fishery in the Baltic Sea.

The social discount rate of the European Union is denoted by $\delta_1$ and the social discount rate of Russia is denoted by $\delta_2$. As mentioned earlier, $\delta_1 < \delta_2 < \infty$. It is assumed that other differences do not exist. Because of the different social discount rates, the objectives in fisheries management are quite different between EU and Russia. For EU the optimal biomass is higher than for Russia, that is, $x_{\delta_1^*} > x_{\delta_2^*}$. EU has then greater incentive to invest in the resource than Russia.

The European Union and Russia begin the co-operation by making an binding agreement about the fishery management. First the parties have to decide about the harvest or proceeds shares, which are allowed to vary over time. In some situations it is possible that the other party does not get any harvest or proceeds at a certain time period. This is however unlikely, and we can assume that it is allowed to make some restrictions to the harvest or proceeds shares. First we examine a situation where the shares do not vary over time, and the parties make an agreement, which lasts, also in the far future. The harvest shares can be based on for example former shares.

The European Union harvest share is denoted by $\alpha$ $(0 \leq \alpha \leq 1)$, which is independent of time. The fishery management preferences are independent of $\alpha$. The objective functionals of the parties can be expressed

\[
P V_1 = \int_0^\infty e^{-\delta t} \alpha[p - c(x)]h(t) \, dt
\]

\[
P V_2 = \int_0^\infty e^{-\delta t} (1 - \alpha)[p - c(x)]h(t) \, dt,
\]

where $PV_1$ denotes EU’s objective functional and $PV_2$ Russian’s. Because the European Union’s harvest share of the cod fishery of is ca. 95%, $\alpha$ could be set to 0.95.
Munro (1979) used Hnyilicza’s and Pindyck’s (1976) method to describe the cooperation. In the agreement the optimal management policy is set to maximize a weighted sum of the objective functionals:

$$\text{max. } PV = \beta PV_1 + (1 - \beta) PV_2, \text{ where } 0 \leq \beta \leq 1.$$ 

The variable $\beta$ is a bargaining parameter, which describes the bargaining power of the parties. If the management preferences of the European Union were entirely dominant, $\beta$ would be 1. In determining the value of $\beta$, Munro (1979) uses Nash’s (1953) theory of two-person cooperative games. It is assumed that the parties can not use side payments.

The profit of the European union is denoted by $\pi$ and the profit of Russia by $\theta$. By varying the value of $\beta$ between 0-1 and determining for each $\beta$ the management policy that maximizes $\beta PV_1 + (1 - \beta) PV_2$, we can obtain the Pareto-efficient solutions. The most likely $\beta$ is reached by solving the game and deciding at what point on the Pareto-efficient frontier the players are most likely to settle.

To measure the bargaining power of the parties, Nash (1953) uses the concept of threat points. These threat points consist of those payoffs, which the parties would get without cooperation. The threat points are denoted by symbols $\pi^0$ and $\theta^0$. With the assumptions made by Nash² the unique solution can be achieved as follows:

$$[3.2] \text{max. } (\pi^* - \pi^0)(\theta^* - \theta^0), \text{ where } \pi^* \text{ and } \theta^* \text{ are the solution payoffs.}$$

If $\pi^*$ and $\theta^*$ corresponds $\beta = \frac{1}{2}$, equal weight would be given to the management preferences of the parties.

Next we examine a situation, where the management preferences of both parties weights, it is, $0 < \beta < 1$. The objective functional can now be written

$$PV = \int_0^\infty \left\{ \beta e^{-\delta t} + (1 - \beta)(1 - \alpha)e^{-\delta t} \right\} p - c(x) h(t) dt.$$ 

² About Nash’s assumptions, see Nash 1953, 136-140.
The Hamiltonian is now

\[ H = \left( \beta \alpha e^{-\delta t} + (1 - \beta)(1 - \alpha)e^{-\delta t} \right) p - c(x) + \lambda(F(x) - h(t)). \]

The optimal biomass time path \( \delta_3 \) is achieved by using the maximization principle and modifying the golden rule\(^3\):

\[
F'(x^*) - \frac{c'(x^*)F(x^*)}{p - c(x^*)} = \frac{\delta_1 \beta \alpha e^{-\delta t} + \delta_2(1 - \beta)(1 - \alpha)e^{-\delta t}}{\beta \alpha e^{-\delta t} + (1 - \beta)(1 - \alpha)e^{-\delta t}}.
\]

The side of the equations can be seen as a weighted average of the discount rates \( \delta_1 \) and \( \delta_2 \). The weighted average is denoted by \( \delta_3 \). It is remarkable, that \( \delta_3(t) \) and \( x^*(t) \) are not independent of time. We also notice that \( \lim_{t \to \infty} \delta_3(t) = \delta_1 \). This can also be seen in picture 1, where one possible outcome is presented.

**Picture 1.** Optimal biomass time path, bargaining without side payments. Source: Munro 1979, 363.

Let us now assume, that the bionomic equilibrium \( x(0) \) is below the perceived optimal biomass levels of both parties. The optimal biomass levels are denoted \( x_{\delta_1}^* \) for EU and \( x_{\delta_2}^* \) for Russia. \( x_{\delta_1}^*(t) \) denotes the biomass time path which have been achieved in the
negotiations. Because the model is linear, the optimal time path is a bang-bang approach. We can see from the picture 1, that the preferences of Russia (high social discount rate) are dominating in the beginning and the near future of the program, but the preferences of EU (low social discount rate) are getting greater weight in the far future.

Next it is assumed that $\alpha$ can vary over the life of the management program. Side-payments are still prohibited. Because $\alpha$ is now a control variable, the $H$ from the Hamiltonian must now be maximized with respect to $\alpha$ at each moment. Differentiating function [3.3] with respect to $\alpha$ we get

$$[3.4] \quad \frac{\partial H}{\partial \alpha} = \left\{ \beta e^{-\delta t} - (1 - \beta) e^{-\delta t} \right\} p - c(x) h(t).$$

Because $e^{-\delta t} < e^{-\delta t}$, $\beta \leq 1/2$ would mean that $\partial H / \partial \alpha$ was positive for all $t > 0$. This would mean that $\alpha = 1$ for all $t > 0$, when $\theta^* = 0$, which would imply that Russia would get nothing from the fishery. In proportion, if $\beta = 0$, $\partial H / \partial \alpha$ would be negative for all $t > 0$, when $\pi^* = 0$.

If $0 < \beta < 1/2$ in the beginning of the management program, then equation [4.4] is negative. The optimal management policy would then produce positive returns for both parties, $\pi^* > 0$ and $\theta^* > 0$. At the beginning of the program $\partial H / \partial \alpha < 0$, which means that $\alpha$ must be set to 0. Anyway there must be some moment $t = T$, where $0 < T < \infty$, when $\partial H / \partial \alpha$ turns positive. The optimal policy would then allow Russia with the high social discount rate to enjoy all profits from the fishery until the moment $T$. Since $T$ EU with the low discount rate enjoys all the profits. The optimal biomass time path $x_{\delta_3^*}(t)$ will consist of $x_{\delta_2^*}$ until $T$ and after that of $x_{\delta_1^*}$. The situation can be seen in picture 2, where $x_{\delta_3^*}(t)$ is bolded. In real life, changing quickly from $x_{\delta_2^*}$ to $x_{\delta_1^*}$ at time $T$ would not be possible.

---

\footnote{As in appendix 2; also notice the impact of $\delta_1$, $\delta_2$ and $\beta$.}
Optimal biomass time path $x_{\delta 3}^*(t)$ consist of $x_{\delta 2}^*$ until $T$ and after that of $x_{\delta 1}^*$.

If the side-payments are allowed, creating the optimal policy is much easier. Then we need just to find a policy that maximizes the sum of the objective functionals $PV_1 + PV_2$. The preferences of both parties are given same weight, it is $\beta = \frac{1}{2}$, and the only thing to decide is the sharing of total returns. If we still assume that $\delta$ is time-variant, the optimal policy will be achieved by setting $\alpha = 1$ for $t > 0$. Then EU with the low social discount rate will be the sole owner of the resource, and will pay side-payments to Russia. Side-payments will concentrate at the beginning of the program, so EU buys out Russia from the fishery.

The sharing of the total returns is as follows: the threat point payoffs are denoted by $\pi^0$ and $\theta^0$ and solution payoffs by $\pi^1$ and $\theta^1$, where $\pi^1 + \theta^1 = \omega$ and $\omega$ (constant) denotes the global return from the fishery. Luce & Raiffa (1967, according to Munro 1979, 364) show that

$$\pi^1 = (\sigma - \theta^0 + \pi^0)/2$$

and

$$\theta^1 = (\sigma - \pi^0 + \theta^0)/2.$$
Luce & Raiffa (1967, according to Munro 1979, 364) interpret the result by saying “each player receives an average of the return it could expect without an agreement and the marginal contribution it makes by accepting the agreement with side-payments”.

### 3.4. IMPACTS OF THE FISHERY COSTS

Next we examine the impact of unequal fishing costs to the fisheries management. Social discount rates of the parties are now same, \( \delta_1 = \delta_2 \), but the fishing costs differ. General level of costs is lower in Russia than in the European Union, so it is assumed that also fishing costs are lower. EU’s unit costs of fishing are denoted by \( a_1 \) and Russian’s fishing unit costs by \( a_2 \), so \( a_1 > a_2 \) and they are independent of the levels of fishing effort. It is also assumed that there are barriers to factor mobility, which are sufficient to maintain this inequality. Unit harvesting cost can be written

\[
c_1(x) = \frac{a_1}{qx},
\]

\[
c_2(x) = \frac{a_2}{qx}.
\]

For any finite, positive biomass level \( c_1(x) > c_2(x) \).

As before, it is assumed that \( \alpha \) is independent of time and sidepayments are not allowed. If harvesting costs are sensitive to the biomass size, EU with higher costs is more oriented towards protection of the cod stock than Russia with lower costs. To solve the problem we again trust in Nash (1953) co-operative two-player theory. If the \( \beta \) arising from the solution is \( 0 < \beta < 1 \), the objective functional can be written as follows:

\[
PV = \int_0^\infty e^{-\delta t} \left[ (\alpha \beta + (1-\alpha)(1-\beta))p - (\alpha \beta c_1(x) + (1-\alpha)(1-\beta)c_2(x)) \right] h(t) dt,
\]

and the Hamiltonian for our problem is

\[
[3.5] \quad H = e^{-\delta t} \left\{ (\alpha \beta + (1-\alpha)(1-\beta))p - (\alpha \beta c_1(x) + (1-\alpha)(1-\beta)c_2(x)) \right\} h(t) + \lambda(F(x) - h(t)).
\]
Using the maximization principle the modified golden rule gives the optimal biomass$^4$:

$$F'(x^*) = \frac{\{\alpha f c_1(x^*) + (1-\alpha)(1-\beta)c_2(x^*)\}F(x^*)}{(\alpha\beta + (1-\alpha)(1-\beta))p - (\alpha f c_1(x^*) + (1-\alpha)(1-\beta)c_2(x^*))} = \delta.$$  

The second term of the left side can be called as the marginal stock effect. The larger $\beta$, the larger will be the marginal stock effect, and the situation will be closer to the optimal biomass of EU. No matter what the size of the $x^*$ is, the optimal path will be bang-bang approach.

Fishing cost can vary also between different groups of fishermen. For trawlers, the size of the biomass is much more important than for gillnetters. When the biomass increases, trawlers’ work gets easier and profitableness arises. (Brady 1997, 73).

When taking into account the fishery costs which are dependent on the biomass size, it is likely that cooperative strategy will lead to higher returns than competitive strategy. The impact of these costs is remarkable especially when there are few actors. The main reason for the attractiveness of cooperative strategy is that it is increasingly important to harvest large stock to get the costs low when the costs are dependent on the biomass size. (Hannesson 1995, 374-375.)

Next we let $\Delta$ vary over time. It is assumed, that marginal stock effect is remarkable and sidepayments are not allowed. Differentiating the equation [3.5] respect to $\Delta$ gives:

\[
\frac{\partial H}{\partial \alpha} = e^{-\delta t} \{\beta [p - c_1(x)] - (1-\beta)[p - c_2(x)]\} h(t).
\]

Previous equation is positive, if the following inequality holds:

$$\beta + \frac{[p - c_1(x)]}{[(p - c_1(x)) + (p - c_2(x))] > 1}.$$  

The second term on the left side of the equation can be called the marginal rent ratio MRR$_1$ of EU. Because $c_1(x) > c_2(x)$, MRR$_1 < \frac{1}{2}$. Therefore $\partial H / \partial \alpha$ is positive only if

\footnote{As in appendix 2; also notice the impact $a, \beta, c_1$ and $c_2$.}
there’s enough weight given to the preferences of EU (β must at minimum exceed ½) to compensate the disadvantage due to higher harvesting costs. While \( MRR_1 < \frac{1}{2} \), \( MRR_1 \) is also an increasing function of \( x \). Indeed \( \lim_{t \to \infty} MRR_1 = \frac{1}{2} \).

Therefore it is possible to find optimal harvest policy, in which both parties can have returns from fishery. We can prove it by examining an unspoiled fish stock \( x(0) = K > x_1^* \), where \( x_1^* \) is the optimal biomass size for EU. If \( \beta \leq \frac{1}{2} \), then

\[
\beta + \left[ p - c_1(K) \right] \left[ (p - c_1(K)) + (p - c_2(K)) \right] < 1.
\]

Previous inequality will hold for all levels of biomass. Implied optimal harvest policy is that only Russia harvests all the time.

If \( \beta > \frac{1}{2} \) and the above inequality reversed, it is possible that EU and Russia harvest in turn. Because \( \beta + MRR_1 > 1 \), \( \partial H / \partial \alpha > 0 \), optimal harvest policy is that only EU harvests all the time.

If the level of biomass in which \( p - c_1(x_1^\infty) = 0 \) is denoted by \( x_1^\infty \), it is possible to find a biomass level \( x_0 \), \( x_1^\infty \leq x_0 < K \), where \( \beta + MRR_1 = 1 \). When \( x \) is reduced over \( x_0 \), \( \partial H / \partial \alpha \) turns negative, which means that \( \alpha = 0 \). Since this moment only Russia will harvest until \( t = \infty \). The biomass will reduce to \( x_2^* \) which is optimal for Russia. The optimal harvest rate will be \( h^* = F(x_2^*) \).

If \( x_0 < x_1 \), according to Munro (1979, 367), there is no reason to assume that aforementioned shift will occur. If \( \alpha = 1 \), optimal harvest policy in all biomass levels will be \( h = h_{\min} \). Because \( x_0 \) is a function of \( \beta \), for both parties to have a return from the resource, \( \beta \) must be large enough that at the starting point of the program \( \partial H / \partial \alpha < 0 \), but small enough that \( x_0 > x_1^* \).

Above it was assumed that \( x(0) = K \). It is also possible, that with optimal harvest policy both parties enjoy returns from the fishery when \( x(0) < K \), given \( x(0) > x_1^* \). In this case EU with higher costs will concentrate on those periods, which are least disadvantageous.
for the global return from the fishery. If \( x(0) < x_2^* \), it is also possible, that both parties enjoy returns from the fishery. In a situation like this the fish stock has grown, and \( \partial H / \partial \alpha < 0 \) for all stock levels below optimum. Optimal harvest policy is to set \( h = h_{\text{min}} \). Only if \( h_{\text{min}} > 0 \), Russia gets returns from the fishery.

If side-payments are allowed the problem gets much easier. Only Russia with low costs will harvest, and buys EU out of the fishery. Sharing the division of the returns of the fishery will happen as told before when dealing with different social discount rates. Both parties will get an average of the payoff it would enjoy in competitive situation and the marginal contribution it makes by accepting an agreement with side-payments. Taking into consideration the Russian fleet capacity at the Baltic Sea and it’s only 5 % share of the cod fishery, it seems very unlikely that Russia will buy out EU.

3.5. DISCUSSION

As mentioned, before the Baltic States and Poland joined the European Union, EU pushed through a prohibition of the cod fishery at the Baltic Sea (Kautsky 2003, 173). In the autumn 2004 we saw that in the IBSFC meeting EU was not able to restrict the fishery of the eastern Baltic cod. This could be an indication that the new EU members have affected EU policy. The new members and also EU25 could be seen less committed to the protection of the Baltic cod than the old EU15. However, EU could still be seen more committed to the protection of the Baltic cod than Russia.

Because the EU share of the cod fishery at the Baltic Sea is ca. 95%, we can assume that the bargaining power of EU is bigger than the bargaining power of Russia. On the other hand, according to Munro (1990, 413-414), one interpretation of the equation [3.2] is that "the relative bargaining power of each player depends upon how much the player stands to lose if the cooperative agreement collapses. The more one is likely to lose from nonco-operation, the weaker is one’s bargaining power.”

Though the share of the Baltic Sea fishery is only 1,5% of the whole Russian fishery, the Baltic fishery has a strong regional significance. In the Kaliningrad region the catch from the Baltic Sea makes up 10-15% percent of the food production. For the region’s
fishing industry the catch from the Baltic Sea makes up 25% of raw material. (Russian federation profile 2004; Kaliningrad Regional Administration 2004.) If the co-operative agreement collapses, the absolute loss could be greater for EU, but relatively smaller than for Russia.

Also the size of the cod stock affects to bargaining power and possible loss. If the cod stock increases through the co-operation of EU and Russia, EU with higher fishing costs would benefit from the situation. This could lead to growing bargaining power of EU. In order to keep the cooperative agreement furthermore attractive for both parties, side-payments must adjust along with the changing cod stock. This question has been studied by e.g. Kaitala & Pohjola (1988).

The simplest form of side-payments is using money. Other side-payments or transfers could be for example transfers relating to trade, debt management or technology. (Carraro & Siniscalco 1993, 323.) From these transfers there is only a short way to issue linking. More protection oriented EU could link other themes to the fisheries policy. This way the cod protection in the Baltic Sea would come more attractive for Russia. With issue linking the bargaining power of EU would probably increase compared to situation where the negotiations are dealing only fisheries policy.

In the field of economic policy, EU could link fisheries policy to themes which are important for Russia, for example the negotiations concerning World Trade Organization (WTO), International Monetary Fund (IMF) or World Bank. Also the one dimension of EU policy, co-operation in the neighbouring countries, would easily fit to be linked to the fisheries policy.

The benefits from the co-operation should be divided so that both parties are satisfied. This means that the co-operation becomes stable. Sharing rules satisfactory core and satisfactory nucleolus introduced by Kronbak (2004) would be feasible. With these rules, we can take into account the contribution that the parties havre made for the agreement and remove the incentive to free-ride. The co-operation would become self-enforcing, when either would not have an incentive to free ride.
Though EU and Russia did not follow ICES recommendations to prohibit the cod fishery at the Baltic Sea in 2005, the prohibition should be considered seriously. Unfortunately there are large economic and social problems linking to the fishery prohibition, which affects specially fishermen and their communities.

During the prohibition of the cod fishery, trawlers are able to harvest other species, but for gillnetters the changing of species is much more difficult. With the help of the prohibition, the cod stock would increase. When the fishery again starts, the harvesting would be more profitable for particularly trawlers. (Brady 1997, 59-73.) So the prohibition could be seen as a successful investment in the resource.

4. CONCLUSION

When the Baltic states and Poland joined the European Union in 2004, the polical situation at the Baltic Sea changed remarkably. The multilateral fishery policy negotiations at IBSFC are turning to bilateral negotiations between EU and Russia. In this study we have examined the new situation by means of game-theory.

The proposals of EU for the TACs in year 2005 have been smaller than Russia´s proposals, so EU can be seen more committed to the protection of the cod stock. Though EU and Russia have not followed ICES recommendations to prohibit the cod fishery at the Baltic Sea, have TACs been declining last years. The prohibition would be justified for the protection of the cod stock and to make the harvesting more profitable after the prohibition. The decline in harvesting costs would benefit specially EU, so the bargaining power of EU would rise.

When taking the unequal harvesting costs into account, according to the model used, Russia would buy out EU from the cod fishery. However, this is not realistic due to the Russia´s 5% share of the fishery, size of the Russian fleet and the barriers to factor mobility. Because of the greater orientation to the protection of the cod stock, EU is assumed to have a higher social discount rate than Russia. Hence the optimal biomass
size is bigger for EU. According to the model used, EU will buy out Russia from the Baltic cod fishery.

The European Union with the greater orientation to the protection of the cod stock could persuade Russia to decline TACs or even accept the fishery prohibition with side-payments and issue linking. With appropriate political links and transfers which accommodate to changing cod stock the co-operation could be made stable and self-enforcing.

The political change at the Baltic Sea offers interesting challenges for further research. The research of the new situation would produce also information for decision-makers. With more accurate, multi-disciplinary research we can produce an ecologically, economically and socially sustainable solution to the Baltic Sea cod fishery.

REFERENCES

2005 fish quotas: Commission proposes more stability through the application of long-term strategies to rebuild stocks. 2004. [online]


Baltic 21 - An Agenda 21 for the Baltic Sea region. 2004. [online]

Brady, M. 1997. An Economic Appraisal of Sweden’s Baltic Cod Fishery - a
bioeconomic model. Examensarbete 168. SLU, institutionen för ekonomi, Naturresurs-
och miljöekonomi. Uppsala.

Carraro, C. & Siniscalco D. 1993. Strategies for the International Protection of the

[online] <URL: http://www.fao.org/DOCREP/005/v9878e/v9878e00.htm>, referred

[online] <URL:

External relations/Enlargement. 2004. [online] <URL:

FAO Fisheries Department. 2004. [online] <URL:


and Practice. Macmillan Press LTD.

Hannesson, R. 1995. Fishing on the High Seas – Co-operation or competition?. *Marine


APPENDIXES

Appendix 1. ICES Fishing areas. [online]

Appendix 2. Deriving the golden rule in the case of sole owner.
Appendix 2. Deriving the golden rule in the case of sole owner.

\[ H = \{ [p - c(x)]h(t) \} + \lambda (F(x) - h(t)) \]

Maximizing the Hamiltonian

FOC (1):

\[ \frac{\partial H}{\partial h} = p - c - \lambda = 0 \]

\[ \frac{\partial H}{\partial x} = -\lambda \]

The net revenue equals the shadow price

\[ \frac{\partial H}{\partial \lambda} = \delta \]

FOC (2):

\[ c'(x)h(t) - \lambda F'(x) = \delta \]

The costate state variable can be reduced by relocating term [1] to its location and relocating term [3] to the location of the time derivative:

\[ c'(x)h(t) - [p - c(x)]F'(x) = -c'(x)[F(x) - h(t)] - \delta [p - c(x)] \]

h(t) terms will reduced:

\[ -[p - c(x)]F'(x) = -c'(x)F(x) - \delta [p - c(x)] \]

By dividing both sides with term –[p - c(x)] and relocating the first term in the right side to the left side we can get the golden rule:

\[ F'(x) - \frac{c'(x)F(x)}{p - c(x)} = \delta \]
Department of Economics and Management Working Papers:

Nro.

- Marko Lindroos ja Anu Raijas (toim.) (2005): Artikkelit Taloustieteen laitoksen opinnäytteenä vuodelta 2004