PhD Project:

Expected and preferred outcomes from introducing ITQ system in the Baltic Sea region.

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About myself

I am from Poland where I completed Bachelor's Degree in Oceanography with Marine Biology specialization. I continued with Master's Degree in Environmental and Resource Management in Esbjerg where I started my PhD as well in September 2011. I am marine environment passionate, diving hobbyist and travel addict.

* Introduction *

The status of worldwide fisheries is examined by United Nations Food and Agriculture Organisation annually. The latest available estimates (FAO, 2010) shows the poor condition of fish stocks around our globe with over half fully exploited and 32 per cent overexploited (28%), depleted (3%) or recovering from depletion (1%). Those stocks leave no room for further expansion or produce yield below maximum potential. This presents a risk of further declines and gives cause for concern for local and international authorities. Therefore, constant progress in research in the area of marine resource management is necessary in order to develop sustainable fishery practices.

The focus of research outlined hereby is the Baltic Sea fishery sector. The Baltic Sea is an inland sea covering an area of 374 000 km^2 surrounded by nine countries (Denmark, Germany, Poland, Russia, Lithuania, Latvia, Estonia, Finland and Sweden). The most commonly mentioned threats to the basin are pollution and overfishing. The catchment area with well-developed both industry and agriculture is source of pollutions (Glatsby and Szefer, 1998) causing effects like eutrophication affecting the local environment (Szlinder-

Richert et al., 2009). This process is accelerated by narrow connection to the North Sea (Sheppard, 2000) resulting with slow water exchange (on average 22 years, MacKenzie et al., 2004). The big pressure on stocks is result of developed over years fishing fleets not balancing the current reproduction potential.

The Baltic Sea fishing activities focus on three most commercially important species: Atlantic cod (*Gadus morhua*), Atlantic herring (*Clupea harengus membras*) and European sprat (*Sprattus sprattus balticus*) which make over 94% of catch in the Baltic Sea (FishStat plus, 2009). Those species form an interacting fish community with number of strong predator-prey linkages (Harveya et at., 2003; Heikinheimo, 2011). Considering those interactions, the proper management regime securing the right abundance and composition of the stocks is of particular interest. Therefore, the research focus is a multispecies model including biological linkages between those three species based on the data on the past fish population abundances, fishing mortalities and predation mortalities by age.

However, biological aspect and an important environment structuring role of those species ensuring stability of the ecosystem is necessary to combine with economic aspects of stocks exploitation. Cod, herring and sprat are very valuable fish in the Baltic and create the base fishing stocks for a large number of fishermen in the region. Therefore, the increase of productivity of the resource presents a potential for the sector and favourable changes may have an important impact on the local economy and labour market concerning the total value added.

*** Research questions – PhD outline ***

The research aims to start with estimation of **cost function for vessels** in Polish fleet divided according to size and gear type into segments, which allows for more detailed view into the fleet characteristics and differences between each type of vessel. The cost function will be also estimated for Denmark in order to compare the fleets and determine, whereas there would be an incentive to trade quotas between member states (article 1). The findings regarding Polish fleet will be used to determine **fleet size and its composition resulted from adaptation to the ITQs system** (article 2). The following step will be the introduction of the biological multispecies model (describing 3-species interaction in the Baltic Sea) which would estimate the stock size of each specie given the harvest in previous year (the biological model used will be one of already developed) and therefore allowing dynamic approach. The biological model integrated with economic model of fishery will allow the **simulations of potential benefits over time given the different variable changes (harvest, fleet size and composition)**. The simulations done over fixed period of time will be compared and the **welfare maximising solution** (article 3). The potential results will be compared with previous experiences with ITQs around the world (review article - article 4).

*** The data ***

The estimation of extended translog multiproduct cost function and further analyses are done for years 2004-2009. The detailed data on the vessel level regarding Polish fishing fleet harvest is available through the courtesy of the Polish Fisheries Monitoring Centre (FMC) in Gdynia which the part of Fisheries Department under the Ministry of Agriculture and Rural Development in Warsaw. The economic indicators are based on data available through Scientific, Technical and Economic Committee for Fisheries (STECF) report: The 2010 Annual Economic Report on the European Fishing Fleet 2011 (STECF, 2011) and include total costs, cost shares and input prices aggregated for segment and size category. Those are divided into individual vessels according to effort and tonnage. The reliability of this assumption is tested through full data set available for Danish fishing fleet which is also used for further comparison of both fleets. The Danish data is available through Statistics Denmark. Additional data regarding spawning stocks biomass is reported by ICES (ICES, 2011).

*** Part 1: Overcapacity of Polish fleet ***

The economics of overcapacity in the Baltic Sea fishing fleets.

The significant problem that the Baltic fishing business faces nowadays is overcapacity leading to poor prosperity of fleets (Döring and Egelkraut, 2008). In the global perspective, it is estimated, that reasonable efficiency in fishery sector requires decrease of about half of capacity (Garcia and Newton, 1997). Thus, for the Baltic Sea management, the fleet efficiency is a key issue and the focus here is on its dynamics**.** The solution expected to notably diminish the lack of efficiency problem is adjusting the fishing fleet size and its composition to each stock reproduction potential. This is expected to improve the profitability and attractiveness of the fishing sector.

The workable definition of fleet overcapacity (FAO, 1998) states, that for a given a fishery resource of a certain size and age structure, the fleet is in excess if the total harvest which could be taken using the full potential is above a set target. Following approach by Clark and Munro (1975), in case of perfect malleability of the fleet implying the replacement unit cost (purchase price) equal the resale price (scrap value), this situation does not occur. The investment in the capital is fully recoverable. The optimal capacity in the light of target biomass level is determined by cost minimizing level of the fleet whereas the excess is removed at no loss. The more realistic situation however claims the replacement cost to be significantly above the resale value. Therefore, the current decisions are highly influenced by past investments. The resource manager is confronted with temporarily 'cheap' capital of a replacement cost above the resale value which is bygone (sunk cost).

Perspectives along the Common Fishery Policy reform

The recently announced Common Fishery Policy Reform (July 2011) proposes introduction of Individual Transferable Quotas (ITQ, called also within the regulation Transferable Fishing Concessions (TFC)) aiming for fishing capacity reduction and increase of economic viability at no cost to the taxpayer, as the system does not require public funding. This is a significant difference considering, that over 2000-2006 period the European Union spent almost one billion EUR for vessels scrapping whereas the fleet capacity was increasing by 3% per year due to fact, that modernised and new vessels were more technologically advanced. In the Individual Transferable Quotas (ITQ) scenario, the more efficient operators have an incentive to increase their concessions while others may decide to leave the industry at adequate compensation. This results in market self-adjustment over time and improvement in the sector.

Methodology

The harvest of fish stocks is performed by decentralized firms owning fishing vessels (often single vessel firm). The fishing industry is a multi-product set of firms. This is because each vessel is harvesting variety of species due to difficulties with perfect selectivity in multi-interactions environment. Therefore, the final catch is a mixture of species existing in the particular area. However, the vessel characterized by specific parameters, equipment and gear is adapted to the particular target specie (or species), what results with harvest composition with some species dominating over others and implying specific cost patterns.

Short-run equilibrium model

A short-run equilibrium model describes the technology through restricted cost function. The cost function is a measurement of minimum cost associated with given level of output for some fixed factor prices and therefore it summarizes information about technological choices available to the firms. It is a classical concept in economics, whereas the first comprehensive treatment is indebted to Hotelling (1932) who analyzed price derivatives of the cost function in the paper on minimizing consumer expenditures subject to a utility level constrain. The restricted version was developed by McFadden (1970) and Lau (1975).

The most general form of cost function is given as $C(w,y)$ where C is a cost with prices of inputs vector (w) and quantities of outputs vector (y) as arguments. However, in the short run, some of the production factors are fixed at predetermined level and therefore the short-run conditional factor demand functions will depend on those. This requires writing the cost function as $C(w,y,K)$ which is restricted in the way that it depends on the existing level of quasi-fixed inputs (K) which are adjustable only partially within a single period (Kulatilaka, 1985). From Hotelling lemma (Hotelling, 1932), $\partial C(w,y,K)/\partial w=x(w,y,K)$, where $x(w,y,K)$ is profit maximizing level of inputs at the given set of prices, outputs and level of quasi-fixed factors. In the long run, the total cost is the sum of variable and quasi-fixed costs and can be given by $TC(w,w_K,y,K) = C(w,y,K) + w_K K$ where w_K is a price vector of the quasi-fixed factors. Minimizing the long run cost function with respect to quasi-fixed inputs while holding the other variables at the observable level, the first order condition states $\partial TC(w,y,K)/\partial K=\partial C(w,y,K)/\partial K+ w_K=0$. Therefore, the solution requires $\partial C(w,y,K)/\partial K=- w_K^*$, where w_K^* is the shadow prices of quasi-fixed factors. Following Squires (1987), Andersen et al. (2008) and Pascoe et al. (2011), the long-run equilibrium is achieved by optimal adjustment of quasi fixed inputs which requires equating the shadow prices of quasi-fixed factors w_K^* equal to the actual prices w_K on the market. Equality $w_K^*=w_K$ implies no incentives for quasi-fixed factors changes. Given this, the optimal equilibrium level of inputs is given by $\partial C(w,q,K^*(w,w_K,q)/\partial w$, where K^* is optimal level of quasi-fixed factors given a set of input prices and quotas for outputs.

The most widely used functional form in modeling of indirect costs in empirical analysis is transcendental logarithmic (translog) function with applied second order Taylor approximation developed by Christiansen et al. (1972). Its main advantages are no restrictions on the elasticities of substitution between factor inputs and possibility for computation of scale economies. The adapted version for fishing industry is developed by Segerson and Squires (1990).

Conclusions

The estimated cost functions for Poland and Denmark are expected to show the differences between efficiency of those two countries within each fleet segment. The results would show if there would be an incentive for ITQs trading between member states if it would be permitted later on and, if so, the direction of potential quotas flow.

* Part 2: Expected outcomes associated with introduction of ITQ *

The commonly recognizable way of overcoming problems with common-property resources, increasing incentive for its preservation, is its privatisation. However, the straightforward solution feasible for land-based resources is difficult in application for the marine fisheries. Therefore, in order to overcome this problem, the economists suggest individual catch quotas as proxies for private ownership.

The harvest of fish stocks is performed by decentralised firms owning fishing vessels (often single vessel firm). Those are regulated by authorities through e.g. limited days at sea, limited entry, restrictions on gear or engine power, by-catch reduction technology (BRT). There is however to some extent room for some decisions regarding input. As the firm is optimizing its own profit and not net social benefit, the final output is expected not to be social optimum. This is due to not taking into consideration the opportunity cost of harvested fish resulting in lack of stock conservation.

The research aims to compare current level of fixed factors (the fleet) with the optimal solution driven by ITQ system keeping the output prices and input costs at the same level and further reveal potential effects of varying prices and costs.

The fleet

The scope of the paper is multifleet fishery, meaning composition of different segments ($seg \in \{DEM, .DRI, PAS, PEL\}$) including vessels sharing similar characteristics simultaneously competing for the same resource. However, the adaptation of each segment to particular harvest technique presents disposition regarding harvested species and, as a result, varying costs for each segment depending on catch composition.

In quota system, the vessel's harvest that would occur under open access (h_{j0}) is restricted to the quota for each specie (q_j) where j = {c - cod, h - herring, s - sprat, o - others). Therefore in the ITQ system: $q_j \leq h_{j0}$. If quotas set are actually restricting the harvest, the profit maximizing vessel is utilizing the total allowance regarding harvest and therefore $h_j = q_j$. Therefore, maximizing the total profit of a single vessel (π), we get:

$$\max_{(\bullet)} \pi = \max_{(\bullet)} \left(\sum p_j q_j - c(\bullet) \right)$$

If the regulations allow quota trade, the harvest of each vessel is restricted by its initial individual quotas (q_i) with the possibility to buy additional quota z_j at market price s_j. Therefore, the vessel's cost is adjusted by the cost of additional quotas bought or sold or sold:

$$\max_{(\bullet)} \pi = \max_{(\bullet)} \left(\sum p_j (q_j + z_j) - c(\bullet) - \sum s_j z_j \right)$$

In this model, the simple cost minimization problem is highly expanded. The cost function is the translog multiproduct cost function estimated in Part 1, harvest is a set of harvested groups and fleet is a set of segments. Then, the profit could be compared with previous profits resulting from TAC system:

$$\max_{(\bullet)} \pi = \max_{(\bullet)}\left(\sum p_j h_j - c(\bullet)\right)$$

The single fisherman profit maximization is then compared with social revenue (Π):

$$\max_{(\bullet)} \Pi = \max_{(\bullet)}\left(\sum p_j H_j - \sum c(\bullet)\right)$$

where H_j is total harvest of specie j.

* Part 3: Social Optimum in ITQ System *

The presented latest suggestions regarding reform of the Common Fishery Policy include introduction of the ITQ system whereas do not specify quotas characteristics or the way of distribution within Member State. The information whereas quotas mean to be temporary or permanent is crucial for fishermen. The tradable quotas encourage efficient and profitable harvest strategy over short-term either way, but incentive for long-term resource conservation depends strongly on the quota duration. This is due to fishermen recognising quotas as a valuable asset which results in favouring enforceable regulations applicable to the whole sector contributing to conservation (eg. regulations regarding mesh-size). The disadvantage of the permanent quotas is dispensing public good to private owners what may be considered unacceptable by the nation in many countries. The annual quotas sold by auction or distributed through lottery do not assure obtaining quota in the future and do not encourage investing in the resource.

In this part the introduced quotas are assumed long-term valid meaning incentive for investment in the fishing capacity. Further, the ITQs are assumed as fixed shares of variable annual quotas (tradable quota shares) due to fluctuations in stocks abundance and initially distributed for free among fishermen.

The final aim of the research is to obtain the model explaining the possibility to reach Optimal Economic Intertemporal Path maximising the revenues from the fisheries while not putting species of interest into risk of extinction or out of biological balance through adjusting the structure of the fleet to optimum over long-term.

The fishing industry

The industry faces perfect elastic demand for outputs and supply curves are perfectly price elastic. The aim is to maximise the net present value of profits from all fisheries together.

$$\max \sum_{t=0}^{T} \rho^{t} \left(\sum \Pi_{t} \right)$$

Π - profit of all vessels in the fleet

ρ - discount rate (assumed constant)

The general equation the dynamics of the stocks follows:

$$B_{t+1,j} = B_{t,j} + G_{t,j} - H_{t,j} \quad \text{i = \{c, h, s, o\}}$$

$B_{t,j}$ - biomass at time t of specie j

$G_{t,j}$ - growth at time t of specie j

$H_{t,j}$ - harvest at time t of specie j

The further used full multispecies bioeconomic model of the Baltic Sea follows approach by Heikinheimo (2011) and includes interactions among three most important commercial fish species. The dynamic of cod, herring and sprat are described by three separate sub-models linked through predation. The species of interest are assumed spatially uniform (populations made up of identical individuals with identical parameters). The strong dependence on environmental conditions, particularly regarding cod stock response (Rockmann et al., 2005), is included in stock-recruitment equation in order to produce more realistic dynamics. This allows evaluating the each specie development of biomass e.g. under different climate scenarios. Full model is presented in Appendix.

The biomass composition of three stocks is constrained so the optimal outcome will keep ecological balance between species. The constraints on minimum viable biomass do not allow eliminating any of the specie.

$$B_{t,j} > B_{\min,j}$$

The controllable part of the stocks dynamics equations is harvest, which is given through total quota available for the country. The available quota is influencing changes in the fleet, as in the efficient system the fleet capacity should reflect the actual stock reproduction potential. Therefore there is dynamics of the fleet size within each of five segments ($K_{t,k}$) described by:

$$K_{t+1,seg} = (1-\gamma)K_{t,seg} + \zeta_{t,seg}$$ seg = {DEM, DRI, PAS, PEL}

Here, ζ indicates the yearly change which will be a subject to defined numerically constraint. The restrictions regarding pace of fleet change are caused by technical and regulatory constraints when it comes to enter and by social and political constraints when comes to exit. The fleet is assumed quasi-malleable (Clark et al., 2005) with positive rate of depreciation $\gamma > 0$. The fleet size unit proposed for application is tonnage [t] of vessels in the fishing fleet.

The fleet change is associated with investment costs c_ζ:

$$c_{\zeta,k}(\zeta) = \begin{cases} c_{I,k}\zeta_k & \text{if } \zeta_j > 0 \\ c_{S,k}\zeta_k & \zeta_j < 0 \end{cases}$$

c_I - cost of one unit of capital purchase (depreciated replacement value - STECF)

c_S - scrap or resale value of one unit of capital (opportunity cost of capital - STECF)

This implies investment costs relation:

$$c_I > c_s > 0$$

The profit of the whole fishery is presented by equation:

$$\Pi_t = \sum \left(p_j H_{t,j}\right) - \sum K_{t,k} c_k(\bullet) - \sum c_{\zeta,k}$$ i=c, s, h

p_j - sell price of specie j

c_k - costs of fishing in segment k, subject to $H_{t,j}$

From social point of view, there is a certain that fleet has to bring minimum profits during fishing season securing reasonable prosperity of fishermen. Therefore profit per vessel's capacity is constrained in the way, that the amount is expected to remunerate capital and labour:

$$\pi_t \geq \eta_{\min}$$

The constraint regarding minimum fleet size prevents results to suggest degrading the fishery sector to marginal importance (history, tradition and culture aspect):

$$K_{t,k} \geq K_{\min,k}$$

For the purpose of simulations, the maximisation is done over fixed period of time using Monte Carlo simulation. The results would indicate intertemporal decision path maximising the whole profit. In this case the 'bang-bang' or most rapid approach path solution would be just partly applicable because of employed constraints.

* Literature *

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