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The Promise of Transferable Fishing Concessions on EU Fisheries

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Abstract

Two of the primary issues of the next Common Fisheries Policy (CFP) reform are maximum sustainable yield (MSY) and transferable fishing concessions (TFCs). The European Commission set the goal of achieving MSY for all European fisheries by 2015. Besides, the European Commission agreed on implementing TFCs under some major principles including reserving a part of total quotas for small-scale fishermen in order to prevent the disappearance of small-scale fishing communities in coastal regions. The interrelation between these two objectives should be well understood. In this study, the impact of fishing on total biomass is analyzed under an age-structured model. Following that, the potential effects of TFCs on the achievement process of the goal of MSY harvesting conditions are explained. This paper shows that the implementation of TFCs, under the major principles defined by the European Commission, has an impact on both the total biomass growth and the time to reach the goal of MSY. The paper concludes that the level of reserved quotas for small scale fishermen does matter since reserving more quotas for small-scale fishermen reduces the time needed to achieve MSY.

Keywords Mechanism Design, Transferable fishing concessions, Maximum sustainable yield, Small-scale fishermen.

JEL code D04, D47, D78, Q22

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1. Introduction

In the course of time, demand for fish has increased, vessels have become larger and hence fishing has become a complex activity not only for fishermen but also for governments. The idea of private ownership or intervention of government was not on the agenda when stocks were abundant and fishing fleets were small. Private ownership of fisheries was banned in England in the 13th century, and fishing was free in English waters till the 19th century (Scott, 2000). The situation was similar in other European countries where both inshore waters and high seas were regarded as common properties. The only limitation agreed upon by European countries was related to the exclusion of foreign fishermen from domestic fishing activities to protect local markets and local fishermen (Scott, 2000). Changes in environmental conditions, uncertainty in fisheries and increasing competition in the fishing industry made researchers and governments highly interested in property rights for management of fisheries. Recently, the European Commission agreed on the implementation of transferable fishing concessions (TFCs) for all European fisheries. TFCs will be distributed by Member States to vessel owners at a fixed percentage of the national quotas for each fish stock.

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In this evolutionary period of the fisheries management, quota allocation mechanisms became one of the most significant issues in output control management systems. These mechanisms for distribution of quotas and secondary markets for quotas are very important for the effectiveness of TFCs in Europe. The European Commission decisively puts emphasis on the sustainability of social welfare and employment in the fishing sector. Thus, the role of distribution and trade mechanisms for fishing quotas comes to the forefront not only for economic concerns but also for the protection of social welfare. In the meantime, maximum sustainable yield (MSY) is one of the other main goals stated in the proposals for the Common Fisheries Policy (CFP) reform package. The European Commission targets to implement MSY harvesting conditions for all European fisheries by 2015. It is undoubted that there is a mutual interaction between the implementation problems of MSY and TFCs. Moreover, these two policies may have interrelated effects on EU fisheries. The mentioned interrelation is going to be shaped by the major principles defined by the European Commission, which are focusing on the protection of the small scale fishing communities. The main purpose of this study is to investigate the promise of TFCs for EU fisheries and demonstrate its possible impacts on the implementation problem of MSY by clarifying the interactions between these two objectives.

The focus of this paper is on the most well-known version of TFC systems, ITQ system, in order to foresee the potential effects of TFC like systems on European fisheries. The rest of the paper is organized as follows. The next section evaluates the advantages and disadvantages of ITQ systems, the most well-known rights based management (RBM) systems. The third section analyzes the possible effects of TFCs on EU fisheries. In the model part, firstly the impact of fishing on total biomass under an age-structured model is explained. Then, the initial quota allocation mechanisms and their impacts on achieving MSY harvesting conditions are discussed in the light of the relevant principles committed by the European Commission. The fourth section concludes.

2. Individual Transferable Quota (ITQ) Systems

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History of implementation of ITQ systems in fisheries management dates back to 1970s. Iceland implemented a completely developed ITQ system in herring fisheries in 1979 and started to implement ITQs in its all important demersal fisheries in 1984 (Arnason, 2007). New Zealand started to implement ITQs in its deep-sea fisheries in 1983 and adopted a uniform ITQ system in its all fisheries in 1986, which was the first such comprehensive ITQ system in the world (Arnason, 2007). Iceland and New Zealand were the leading countries for the implementation of ITQ systems. Following these advances in fisheries management, many papers has been written on the advantages and disadvantages of ITQ systems. Geen and Nayar (1988), Arnason (1993), Gauvin et al. (1994) and Buck (1995), analyzed ITQ systems in the late 1980s and 1990s. These studies promoted the efficiency of ITQ systems by showing the possibility of reductions in overcapacity and elimination of 'race to fish' under ITQ regimes. Furthermore, Grafton and McIlgorm (2009) performed cost-benefit analysis of ITQ systems for the Australian fisheries. Higashida and Takarada (2009) and Higashida and Managi (2010) discussed the efficiency of ITQ systems under different market conditions.

Besides the strong scientific arguments in support of ITQ systems, there is also a literature discussing inefficiencies of these systems focusing on high management costs and imperfect market conditions such as unstable quota prices or improperly functioning secondary markets for quotas. Anderson (1991) mentioned that the total cost would not be minimized under imperfectly competitive market conditions under ITQ systems. Newell et al. (2005) stated that ITQs can only be a solution for the long-run since unstable quota prices are observed in the short-run. Vestergaard (2005) pointed out that achieving efficiency for fishing fleets under an

ITQ system would be delayed due to sunk costs. See also Chavez and Stranlund (2013) for a model of ITQ management system with management costs and their effects on the secondary quota markets.

The quota allocation mechanisms always lie at the heart of these discussions about ITQ systems. For real-life applications of these mechanisms in different fishing regions, the reader is referred to Shotton (2001) and Cox (2009). The results of the current paper also imply that the design of the (initial) quota allocation mechanisms is very important to achieve sustainable fisheries. In addition to the existing literature, this paper models the impact of fishing on total biomass and discusses the implementation of TFCs in tandem with the implementation of MSY harvesting conditions under an age-structured model. In order to clarify the economic and social impacts of the TFCs in more details, the advantages and disadvantages of the ITQs are explained in the next subsection.

2.1 The Advantages and Disadvantages of ITQ Systems

The purpose of implementing the ITQ management system is to increase market functionality by providing flexible conditions and at the same time to create a self-control mechanism in the fishing industry for sustainable fisheries. There are two key management decisions in traditional fisheries management. The first one is the target biomass and hence fishing effort (or harvest) for a given species. The second one is the decision on the instruments to achieve this target (Grafton and McIlgorm, 2009). Likewise, determining the TACs and quotas, issuing the rules on transfers of quotas and establishing the control systems are the building blocks of an ITQ management system. Thus, under an ITQ system and the policy of achieving MSY harvesting conditions, estimating the MSY level and appropriate TACs, creating an effective design for the initial quota allocation process and secondary markets for quotas become the most important steps of the implementation process of the management system.

There are several reasons why ITQs became one of the most popular management systems in fisheries, and why ITQs are widely accepted worldwide. First of all, ITQ programs are intended to reduce overcapitalization, positively impact the conservation of stocks, improve the market conditions and promote safety in fishing fleets (Buck, 1995). Moreover, ITQs guarantee a catch share and this property of ITQs slows or eliminates the ‘race to fish’ and allows fishermen to be flexible about their timing and fishing rate decisions (Buck, 1995). As one of the key

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parameters used for measuring the economic efficiency, resource rents can also be used to evaluate the efficiency of the management system. Resource rents are increased returns per unit effort, and they occur when management systems such as ITQs reduce the level of fishing effort, which is resulted in the exit of less efficient operators and increase in catch per unit of effort (Geen and Nayar, 1988). Geen and Nayar also show that resource rents under ITQ systems would be 25% higher than the resource rents under alternative management systems for the same total catch. The resource rents in the European fisheries will also be affected by protective regulations of the European Commission. By these regulations, total resource rents may decrease as a result of the relevant principles stated in the CFP reform proposals that put emphasis on protecting small-scale fishermen who are less efficient operators. On the other hand, these new policies may increase equity in the distribution process of resource rents.

It is illustrated in the Commission Staff Working Document that ITQ systems significantly reduced the total fleet capacity in the United States surf clam and ocean quahog fisheries, the Australian bluefin tuna fishery and Iceland's purse seine fishing (EC, 2007). On the other hand, Geen and Nayar (1988) state that the average catches per boat in Western Australia and South Australia under the ITQ system to be respectively 67% and 28 % higher than the average catches which might have been under aggregate quota or limited entry system, and also 90% higher in Western Australian system if they have maintained to implement previous aggregate quota system. However, elimination of high cost vessels is not a solution when the total social welfare is considered since another aspect of transferable quota systems is the reduction in total employment. Under ITQ systems, total employment decreases due to the exits of fishing vessels from the industry. For example, there has been %86 decrease in the number of fishing vessels in Iceland herring fishery after implementation of the transferable quota system (Edwards, 2000). Employment in the fish catching sector is highly affected from decreasing number of vessels rather than employment in processing and aquaculture sectors.

Employment in sub-sectors of fisheries in 1996-8 and 2005 is given in Figure 1. It shows the changing employment levels in sub-sectors of fisheries (23% decrease in the total employment in the EU-15). Note that the decline in employment level was experienced intensely in the fish catching sector (31%), whereas the decline in the processing sector employment was around 1%.

Figure 1. Employment in fisheries sub-sectors in the EU

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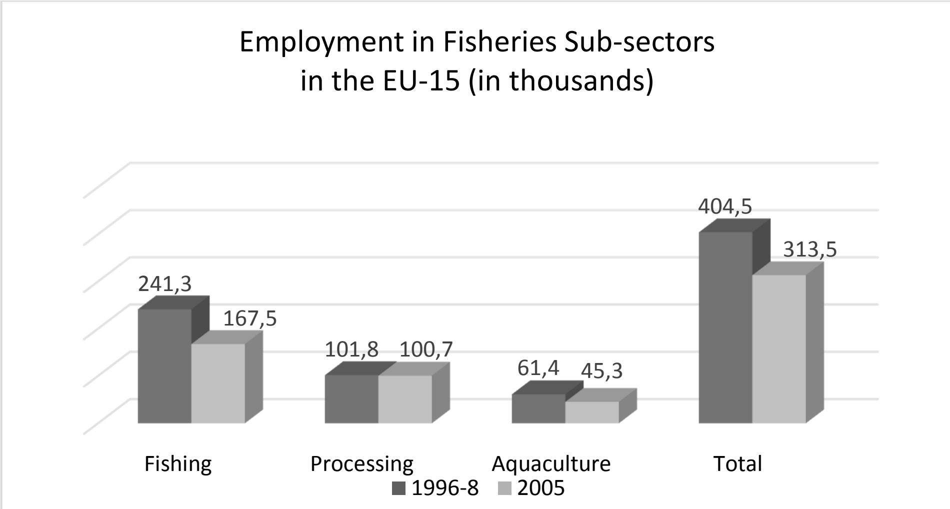

Source: EC, 2006b.

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In the last decade, traditional fishing techniques has been affected from new technologies used in fish catching. The technological developments may be one of the main reasons for decreasing employment in the fish catching sector. Another reason for decreasing employment in the fish catching sector is the elimination of small-scale fishermen under new market conditions. Therefore, the number of employees may decrease in the fish catching sector due to the reduction in the number of vessels unless protective regulations are issued.

Many studies on ITQs emphasize that ITQs create positive net returns for the fishing industry if these programs are managed effectively. Principally, there are some pre-conditions to be satisfied for successful implementation of ITQ programs. These pre-conditions are defined as adequate monitoring and control, well defined and binding TACs and flexibility in reconciliation of quotas (Grafton and Mcllgorm, 2009). According to Kompas and Che (2003), there are two necessary conditions at least to render ITQs efficient in management of fisheries. Firstly, there should be a well-organized market to implement transfer of quota effectively. Secondly, quota holders should participate in the quota market in order to transfer quotas from high to low marginal cost producers, and also there should be an ex post transfer to compensate catches which are different from planned or prior quota holdings (Kompas and Che, 2003).

Despite its effective outcomes such as reducing race to fish and overcapacity, ITQ systems may cause some negative results such as increasing discards and high grading. These consequences of ITQs lead to questions about the net benefits of ITQ systems. ITQs can create incentives to discard lower valued fish since returns from catches will increase if fishermen fill their quotas by catching higher valued fish rather than lower valued ones (Geen and Nayar, 1988). The other much-debated issue about ITQ systems is the increasing management and production costs under ITQs. Fixed costs, information costs and costs of control are due to change under ITQ management systems. Information costs are higher under ITQ management and other TAC-based systems compared to the systems which simply regulate fishing effort (Yandle and Dewees, 2008). Implementation of ITQs may also increase the fixed costs of production because of the ‘user pays’ principle for government services. This principle prescribes payments by fishermen to cover a portion of management costs in fisheries. Hence, the management levy paid by each fisherman is also high under ITQs (Geen and Nayar, 1988). On the other hand, total government financial transfers are much higher under input control systems than output control systems. Grafton et al. (2006) state that the total government transfers were on average 20% of the total landings value in OECD countries in 1999 while it reduced to 4% in New Zealand and Iceland under individual transferable quota systems. Hence, besides the increasing costs of control, ITQ systems may reduce the financial burden on governments by decreasing the government transfers.

To sum up, decreasing employment level in the fish catching sector, increasing highgrading and discards and higher costs under some implementations are the pronounced problems of ITQ systems. The recent CFP reform aims to overcome these problems by putting some restrictions on the transferability of quotas, increasing output controls and determining TACs according to MSY approach, which make the next CFP reform a corner stone for European fisheries.

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3. Reform of the CFP: Implementation of TFCs

The EU represents about 4.60% of global fisheries and aquaculture production, which makes the EU the 4th largest fish and fish products producer after China (32.80%), India (5.20%) and Peru (5.20%) (EC, 2010a). Furthermore, catches in the EU constitute the 3rd largest catch volume (5.70%) after China (16.30%) and Peru (8%) (EC, 2010a). Nevertheless, as a result of high demand for fish, European countries import fish and fish products in spite of high levels of fish production in Europe. Besides, the fishing industry is important not only for supplying food to consumers or fish products to different industries but also for creating employment opportunities and generating primary sources of income in some coastal areas, such as Galicia in Spain, Algarve in Portugal and Voreio Aigaio in Greece (EC, 2010b).
The general belief is that the next reform package may increase the efficiency in the fishing sector by implementation of TFCs. Furthermore, the next CFP reform also focuses on providing sustainable fisheries by implementing MSY harvesting conditions while preserving social

welfare and employment opportunities in the fishing industry under a well-designed TFC system. Transferable fishing concessions will be introduced by all Member States (MS). Moreover, TFCs will be implemented by MS under some major principles determined by the European Commission. These major principles are described by the European Commission as follows (EC, 2013):

- "Determining a maximum percentage of total national quotas that can be given to any vessels,
- Reserving a part of national quotas to small-scale fishermen and allocating the rest of the quotas as TFCs,
- Reserving a minimum quota level for only new entries,
- Putting restrictions on selling, leasing or swapping of TFCs that only the owners of licensed and active vessels can buy TFCs in order to use them for licensed and active vessels,
- Showing respect to the principle of relative stability,
- Withdrawing the TFCs of a vessel owner by the state in case of a serious infringement by the vessel owner."

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The principles above are important steps for increasing total economic profitability and employment in the fish catching sector. As emphasized before, the other primary concern of the CFP reform is achieving MSY harvesting conditions by 2015 for all European fisheries. The MSY is the optimal catch level while protecting the fish capacity to sustain regeneration for the future. MSY harvesting conditions at the population equilibrium provides the highest level of total biomass growth and hence the highest level of yield. In this study, it is not adequate to determine only the total biomass level at MSY (B_{MSY}) since age distribution of the population is also important. The main intuition for this claim is that different age distributions for the fish population at the same level of total biomass may result in different levels of biomass growth since each age group has different fertility rates. Thus, in order to achieve MSY harvesting conditions, it is not only enough to determine the total allowable catch which brings the population to the MSY level of total biomass. The next subsection begins with analyzing the impact of fishing on the total biomass, and then continues with the implementation problem of MSY harvesting conditions under TFCs.

3.1 The Impact of Fishing on Total Biomass

One of the main results of the paper is related to the impact of fishing on the total biomass growth under an age structured model. The age-structured fish population dynamics are described by three age classes following Skonhoft et al. (2012) and Kanık and Küçükşenel (2013):

Juveniles, $X_{0,t}$ (age < 1)

Young matures, $X_{1,t}$ (1 ≤ age < 2)

Old matures, $X_{2,t}$ (2 ≤ age)

The juveniles refer to the youngest class in the population. The juveniles are not harvestable, and also they are not members of the spawning stock. The old and young mature classes are both harvestable and members of the spawning stock. Different than young matures, old matures have higher fertility as supposed by Reed (1980). Moreover, weight per fish is higher for old mature fish than young mature fish ($w_0 < w_1 < w_2$). Two possible cases at any given year or time t are considered: fish stock dynamics without fishing and fish stock dynamics with fishing. The aim is to reveal the effects of management systems or quota allocation mechanisms on the total biomass growth. It is first assumed that the planner is myopic and/or allocation of fishing rights are not permanent. That is, fishing management plans are designed annually and hence fishing rights are granted on a yearly basis. The total biomass with fishing at time t+1 is denoted by B_{t+1} and the biomass of age class i at time t+1 is denoted by $X_{i,t+1}$. Similarly, B_{t+1}^* and $X_{i,t+1}^*$ refer to the total biomass and the population of age class i at time t+1 without fishing.

In this study, the authors employ the Beverton-Holt recruitment function, which is increasing and concave for both age classes (Beverton and Holt, 1957). The number of recruits to the fish population at time t is:

$$X_{0,t} = R(X_{1,t}, X_{2,t}) = a(X_{1,t} + \beta X_{2,t})/[b + (X_{1,t} + \beta X_{2,t})] \quad (1)$$

The number of recruits is a function of the size of the old and young mature age classes and parameters of a, b and β. The scaling and shape parameters are denoted by a and b, respectively. Moreover, $\beta > 1$ is the fertility parameter indicating that the natural fertility rate of the old mature fish is higher than the natural fertility of young mature fish. The total biomass at time t after spawning is:

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$B_t = w_0 R\left(X_{1,t}, X_{2,t}\right) + w_1\, X_{1,t} + w_2\, X_{2,t}.$

For the first case in which there is no fishing, the total biomass at time t+1 after spawning is defined as the following:

$$B_{t+1}^{*} = w_0 R(X_{1,t+1}^{*}, X_{2,t+1}^{*}) + w_1 X_{1,t+1}^{*} + w_2 X_{2,t+1}^{*}.$$

At time t, there are new recruitments to the population at an amount of $R\left(X_{1,t}, X_{2,t}\right)$ and these new recruits constitute young mature fish population at time t+1. That is, $X_{0,t} = R(X_{1,t}, X_{2,t})$, $X_{1,t+1}^{*} = s_0\, X_{0,t}$, and $X_{2,t+1}^{*} = s_1\, X_{1,t} + s_2\, X_{2,t}$. Given this transition equations, the total biomass (without fishing) at the beginning of time t+1 is:

$$B_{t+1}^{*} = w_0 R\left(X_{1,t+1}^{*}, X_{2,t+1}^{*}\right) + w_1\, s_0\, R\left(X_{1,t}, X_{2,t}\right) + w_2 (\, s_1\, X_{1,t} + s_2\, X_{2,t}) \,.$$

In order to measure the total biomass change between time t and t+1, the difference between B_{t+1}^{*} and B_t is taken. Let ρ^{*} be the total biomass change between time t and t+1, where

$$\begin{aligned} \rho^{*} &= B_{t+1}^{*} - B_t \\ &= w_0\, R\left(X_{1,t+1}^{*}, X_{2,t+1}^{*}\right) - w_0\, R\left(X_{1,t}, X_{2,t}\right) + w_1\, s_0\, R\left(X_{1,t}, X_{2,t}\right) + w_2\, s_1\, X_{1,t} + \\ &\quad w_2\, s_2\, X_{2,t} \; - w_1\, X_{1,t} - w_2\, X_{2,t}\,. \end{aligned}$$

On the other hand, for the second case with fishing, the total biomass at time t+1 is defined as the following:

$$\begin{aligned} B_{t+1} &= w_0\, R\left(X_{1,t+1}, X_{2,t+1}\right) + w_1\, X_{1,t+1} + w_2\, X_{2,t+1} \\ &= w_0 R\left(X_{1,t+1}, X_{2,t+1}\right) + w_1\, s_0\, R\left(X_{1,t}, X_{2,t}\right) + w_2 \sum_{i=1}^{2} s_i\, \left(1 - f_{i,t}\right) X_{i,t}\,. \end{aligned}$$

In the above equation, the total fishing mortality rate (or exploitation rate) of age group of $i \in \{1,2\}$ at time t is denoted by $f_{i,t}$ where $f_{i,t} \in [0,1]$. Thus, $f_{i,t} = 0$ means that there is no harvesting of age class of i at time t, and $f_{i,t} = 1$ means that all of the fish population in the age class of i is harvested by fishermen at time t. Note that $X_{2,t+1} = s_1\left(1 - f_{1,t}\right) X_{1,t} + s_2\left(1 - f_{2,t}\right) X_{2,t}$. Given this formulation, the change in the total biomass for the second case is equal to ρ where

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$$\rho = B_{t+1} - B_t$$

$$= w_0\, R\big(X_{1,t+1}, X_{2,t+1}\big) - w_0\, R\big(X_{1,t}, X_{2,t}\big) + w_1\, s_0\, R\big(X_{1,t}, X_{2,t}\big) + w_2\, s_1\, X_{1,t} + w_2\, s_2\, X_{2,t} - w_2\, s_1\, f_{1,t}\, X_{1,t} - w_2\, s_2\, f_{2,t}\, X_{2,t} - w_1\, X_{1,t} - w_2\, X_{2,t}.$$

The one year net impact of fishing on total biomass is the difference between the total biomass change from time t to time t+1 for the first case and the total biomass change from time t to time t+1 for the second case, ($\rho^* - \rho = B^*_{t+1} - B_{t+1}$), which is equal to:

$$\rho^* - \rho = w_0\big[R\big(X^*_{1,t+1}, X^*_{2,t+1}\big) - R\big(X_{1,t+1}, X_{2,t+1}\big)\big] + w_2\big(s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t}\big) \qquad (2)$$

In the fishing fleet, there are $N = |S \cup L|$ fishermen characterized by their fishing selectivities and harvest capacities. Let S be the set of small-scale fishermen operating inshore, and L be the set of large-scale fishermen operating off-shore. Let $j_i \in [0,1]$ be the fishing selectivity or technology of fisherman i. Let c_i be the harvest capacity of fisherman i where $c_i > c_k$ for all $i \in L$ and all $k \in S$. The fishing selectivity determines the catch composition of a fisherman. The total biomass harvest of fisherman i at time t, $h_{i,t}$, consists of $100 j_i$ percent of old mature fish and $100(1 - j_i)$ percent of young mature fish. If $j_i = 1$, the fisherman can perfectly select for the old mature age class. That is, the fisherman can harvest only old mature fish due to perfect selectivity. Similarly, if $j_i = 0$, the fisherman can perfectly select for the young mature age class. The fishing selectivity is imperfect for the other possible cases where $j_i \in (0,1)$. Small-scale fishermen are coastal fleets which target the old mature fish and harvest more old mature fish than young mature fish, compared to large-scale fishermen. Large-scale fishermen have higher ratios of young mature fish harvest compared to coastal fleets. That is, $j_i > j_k$ for all $i \in S$ and all $k \in L$. As pointed in Turris (2000), small-scale fishermen focus on harvesting quality products, old mature fish in our environment, rather than large volumes. Moreover, small-scale fishermen can be interpreted as coastal vessels and large-scale fishermen can be interpreted as trawlers. This type of selectivity is also observed in real world fisheries. For example, Armstrong (1999) characterizes Norwegian fisheries with these two types of vessels. Coastal vessels are operating inshore and trawlers are mostly operating off-shore. In this fishing environment described by Armstrong (1999), coastal vessels are tend to catch old mature fish at a higher ratio since mature fish migrate to coastal areas for spawning; on the other hand, trawlers, which operate off-shore, catch more young mature fish than old mature fish.

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Fishing rights or quotas defined as privileges to harvest a certain fraction of the total allowable catch (TAC). The TAC is set each year as a function of the biomass of mature fish ($TAC_t(X_{1,t}, X_{2,t})$). It is also assumed that $\sum_{i \in S} c_i < TAC_t$ which means that total harvest capacity of small-scale fishermen is not very large. That is, they will not be able to harvest all of the total allowable catch if all quotas are assigned to small-scale fishermen. Let $\alpha_{i,t} \in [0,1]$ be a quota, a percentage of the total allowable catch, that fisherman (or vessel) i owns at time t. There is no waste of quota and fishermen can fill their quotas if it is profitable to do so. That is $c_i \geq \alpha_{i,t} TAC_t = h_{i,t}$ for all t and all $i \in N$. Denote $\alpha_t = (\alpha_{1,t}, \dots, \alpha_{N,t})$ as a feasible quota allocation at time t where $\sum_{i \in N} \alpha_{i,t} = 1$ for all t, and α_0 as the initial quota allocation. This means that the fishery moves from open access to the rights-based management system at $t = 0$. There are different allocation methods used in major fisheries to determine the initial allocation of quotas: historical catch, auction, equal share and combination of these methods. Historical catch was used in 54% of the fisheries, combination of the methods was used 37% of the fisheries, equal sharing rules were used in 6% of the fisheries, and auctions were used in 3% of the fisheries[3]. If the quotas are permanent and nontransferable, $\alpha_{i,0} = \alpha_{i,t}$ for all t and all i. If quotas are transferable then there might be a time t where $\alpha_0 \neq \alpha_t$. There may also be some restrictions on the transferability of quotas in the secondary markets. For example, the quotas assigned to small-scale fishermen may not be transferable. That is, $\alpha_{i,0} = \alpha_{i,t}$ for all t and $i \in S$. Let $R_S = \sum_{i \in S} \alpha_{i,0} \in [0,1)$ be the total nontransferable quota reserved for small-scale fishermen[4]. Since these restrictions affect the final quota allocation ($\alpha_{i,t}$) at a given time t, the impact of fishing on total biomass change depends on these restrictions. If fisherman i bought (sold) some quotas at time t in the secondary market, then $\alpha_{i,t} > \alpha_{i,t-1}$ ($\alpha_{i,t} < \alpha_{i,t-1}$). It is assumed that secondary markets for quotas are perfect. That is, the secondary markets are frictionless, and liquid. The details of the secondary market for quotas are not necessary for the general purpose of this article. See Ledyard (2009) for more details about secondary markets for quotas in fisheries.

Given the above information the profit of fisherman i is

$$\pi_{i,t} = p_{2,t} j_i \alpha_{i,t} TAC_t + p_{1,t}(1 - j_i)\alpha_{i,t} TAC_t - q_t(\alpha_{i,t} - \alpha_{i,t-1}) - C_i(X_{1,t}, X_{2,t}, h_{i,t}, j_i),$$

where $p_{i,t}$ is the market price of mature age class i at time t, q_t is the price per quota at time t, and $C_i(.)$ is the cost of fishing which depends on the total number of old and young mature fish,

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[3] See Lynham (2014) for more details about the allocation methods used in major fisheries.

[4] $R_S < 1$ since $\sum_{i \in S} c_i < TAC_t$.

total harvest of fisherman i and his fishing selectivity. Depending on the cost structure of a fisherman he may prefer to sell or buy quotas in secondary markets for quotas. Large-scale fishermen are more efficient than small-scale fishermen. That is, $MC_i > MC_j$ for all $i \in S$ and all $j \in L$. The additional details of the cost function is not necessary for calculating MSY. However, it is important for the calculations of maximum economic yield (MEY) which is outside the scope of this paper. Note that if all quotas are transferable small scale fishermen sell their quotas to more efficient large scale fishermen and exit the market. However, this is not the case in this model since the quotas assigned to the small scale fishermen are not transferable.

The equation (2) implies that the impact of fishing on total biomass change depends on fishing mortality rates (or exploitation rates) of old and young mature fish. Since fishermen have different fishing selectivities and hence different catch compositions of old and young mature fish, the impact of fishing and the number of new recruitments to the total biomass depend on fishing selectivity of each fisherman. Given a fishing selectivity of a fisherman, his harvest consists of old and/or young mature fish. That is, fishermen catch different biomass weights of old and young mature fish depending on their fishing technology. If the fishing selectivity of a fisherman is high (small-scale fisherman) then he catches relatively less young mature fish. Thus, fishing selectivity of fisherman is a determinant for computing the total catch distribution of old and young mature fish of a fisherman. Accordingly, levels of $f_{1,t}X_{1,t} = \sum_{i\in N}[(1-j_i)\alpha_{i,t}TAC_t]$ and $f_{2,t}X_{2,t} = \sum_{i\in N}[(j_i)\alpha_{i,t}TAC_t]$ depend on the fishing selectivity, the final quota levels and hence the catch compositions of fishermen. The main result of this section can now be stated.

Result 1: Quota allocation mechanisms and restrictions on the transferability of quotas are determinants to reduce the effects of fishing on the total biomass.

Proof: According to the equation (2), the impact of fishing can be minimized by maximizing $X_{2,t+1}$ since $X^*_{1,t+1} = X_{1,t+1}$ and by minimizing $w_2(s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t})$. That is, the difference between $R(X^*_{1,t+1}, X^*_{2,t+1})$ and $R(X_{1,t+1}, X_{2,t+1})$ is shaped only by the total population of the old mature age class. The difference between the total population of the old mature fish without fishing and with fishing is equal to $s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t}$. This implies that the function, $w_2(s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t})$, is the objective function of the minimization problem. If the given objective function is minimized, then $X_{2,t+1}$ is maximized and the difference between the recruitment functions is minimized. As a result, the impact of fishing is

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minimized. Since w_i and s_i values are constant, minimizing the impact of fishing just depends on the rates of total fishing mortalities for different mature age classes. There are three possible cases. If $s_1X_{1,t} > s_2X_{2,t}$ at the initial point of the fish population, then the impact of harvesting old mature fish is less than the impact of harvesting young mature fish to the total biomass change of the fish population. On the other hand, if $s_1X_{1,t} < s_2X_{2,t}$, the results are reversed. That is, the impact of harvesting old mature fish is higher than harvesting young mature fish. Finally, if $s_1X_{1,t} = s_2X_{2,t}$, then either harvesting old mature fish or young mature fish results in the same impact of fishing. Let without loss of generality $s_1X_{1,t} > s_2X_{2,t}$, which is a more realistic case since the survival rate of old mature fish tends to be less than the survival rate of the young mature fish and also the number of young mature fish is usually higher than the number of old mature fish. In this case, switching one unit harvest of young mature fish with one unit harvest of old mature fish is always preferable to minimize the impact of fishing on total biomass. This implies that small scale fishermen have less negative impact on the total biomass per unit of harvest than large scale fishermen. Note also that $f_{1,t}X_{1,t} = \sum_{i\in N}[(1-j_i)\alpha_{i,t}TAC_t]$ and $f_{2,t}X_{2,t} = \sum_{i\in N}[(j_i)\alpha_{i,t}TAC_t]$ and final quota allocations depend on the initial quota allocation. Since there are restrictions on the transferability of quotas, this will affect the final allocation of quotas, $\alpha_{i,t}$. If there are no restrictions on the transferability of quotas, quotas would be concentrated on the large scale fishermen since they are more cost efficient. Thus, restrictions on transfer of quotas affects the impact of fishing on the total biomass. □

3.2 Achieving MSY under TFCs

Member States have agreed to manage EU fish stocks at MSY (EC, 2006a). Under the MSY approach, the management goal of the EU is to produce both economically and biologically sustainable harvest levels. Currently, most of the fish stocks are overfished with respect to MSY harvesting conditions (Da Rocha et al., 2012). For example, 13 of fish stocks out of 14 different evaluated fish stocks are overfished with respect to MSY in Western Waters Area (EC, 2012).

Despite of the recent developments in the EU on achieving MSY, MSY approach is not today's issue. Moreover, the roots of this objective date back to 1982 UN Convention on the Law of the Seas. However, implementation of necessary policies have iterated up to today. Besides, the way of finding the most accurate estimation of MSY is highly discussed by scientists. Some of the estimations for MSY do not consider the age-structure of fish populations. Those

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approaches do not take into account the different fertility rates at different ages, but only consider the weight of fish while measuring the effect of harvesting on total biomass. However, considering the age-structure of the fish population results in more accurate estimations for MSY. The most common methods for the estimation of MSY are Scheafer (1954) and Fox (1970) models. Recently, Skonhoft et al. (2012) applied a simple Lagrangian method to find fishing mortalities for the old and young mature fish at MSY under an age-structured model. They show that if $\frac{w_2}{s_2} > \frac{w_1}{s_1}$, then fishing mortality rates are $f_2^{MSY} = 1$ and $0 < f_1^{MSY} < 1$ at the population equilibrium. Moreover, the total number of fish in each age class is $X_1^{MSY} = s_0 a - \frac{b}{1+\beta(1-f_1^{MSY})}$, $X_2^{MSY} = s_1(1 - f_1^{MSY})X_1^{MSY}$, and $X_0^{MSY} = R(X_1^{MSY}, X_2^{MSY})$. Given this the total biomass at MSY is defined as $B_{MSY} = w_0 X_0^{MSY} + w_1 X_1^{MSY} + w_2 X_2^{MSY}$.

In the previous subsection, the impact of fishing on the total biomass is investigated. Since catch compositions of fishermen depend on their fishing selectivities, the impact of fishing on total biomass for every period depends on the quotas held by each type of vessels in that period. The main problem for European fisheries is that total biomass levels are less than the estimated total biomass at MSY for almost all economically valuable fish stocks. Thus, in this study, the situation in which the initial total biomass levels are less than the one at MSY (B_{MSY}) is investigated and the interrelation between TACs and MSY for a single species fishery is explained. Let's suppose that the initial population is at a biomass level less than B_{MSY} at time t, and at B_{MSY} at time t^*. The authors compare the time needed to achieve B_{MSY}, $t^* - t$, under different quota allocations, restricted transferability of quotas and on the path of stationary actions in which fishing mortality rates are time independent. Furthermore, the impact of initial quota allocation on the time duration to achieve MSY harvesting conditions is investigated. To be able to make this comparison, the convergence rate or population growth rate at each period under different quota allocations and restricted transferability of quotas is considered.

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According to the discussion in the previous section, the change in the total biomass from recruitment time $t+n+1$ to $t+n$, where $0 < n \le t^* - t$, is equal to the following equation:

$$\rho_{t+n} = w_0\left[R(X_{1,t+n+1}, X_{2,t+n+1}) - R(X_{1,t+n}, X_{2,t+n})\right] + w_1 s_0 R(X_{1,t+n}, X_{2,t+n}) + w_2(s_1 (1 - f_{1,t+n}) X_{1,t+n} + s_2(1 - f_{2,t+n}) X_{2,t+n}$$

Under meaningful TACs where $TAC_t = f_{1,t}X_{1,t} + f_{2,t}X_{2,t} > 0$, maximizing the total biomass growth for every period will minimize the time required to achieve MSY harvesting conditions which result in the maximized growth of population at the total biomass level of B_{MSY}. Therefore, in order to have higher growth rates and less time for achieving MSY, the equation above should be maximized for every period. Hence, to maximize the total biomass growth for this period, both $R\left(X_{1,t+n+1}, X_{2,t+n+1}\right)$ and $w_2(s_1\ (1-f_{1,t+n})\ X_{1,t+n} + s_2(1-\ f_{2,t+n})\ X_{2,t+n})$ have to be maximized given population parameters, $X_{0,t+n}$, $X_{1,t+n}$, and $X_{2,t+n}$. The second term is maximized by minimizing $f_{1,t+n}$ and maximizing $f_{2,t+n}$ since $s_1 X_{1,t} > s_2 X_{2,t}$. Similarly, $R\left(X_{1,t+n+1}, X_{2,t+n+1}\right)$ is maximized by minimizing $f_{1,t+n}$ and maximizing $f_{2,t+n}$ since $X_{1,t+n+1} = s_0 X_{0,t+n}$, $X_{2,t+n+1} = s_1\ (1-f_{1,t+n})\ X_{1,t+n} + s_2(1-\ f_{2,t+n})\ X_{2,t+n}$ and the numbers of recruits are positively correlated with the numbers of old mature fish. As a result, a decrease in the young mature fish population has a greater effect on the new recruitments to the population in the future. To achieve the maximum growth of total biomass at each period, having one more unit of fishing mortality for the old mature fish class is always preferable to having one more unit of fishing mortality for the young mature fish class. Therefore, the fishing mortality of the old mature fish should be maximized and the fishing mortality of the young mature fish should be minimized at each period to converge the total biomass target at a shorter time duration in any stationary path converging to MSY harvesting conditions. Note that not only the total population size but also the total biomass proportion and size of each age class is also important to achieve MSY conditions in a dynamic framework.

Figure 2. MSY for an age-structured fish population

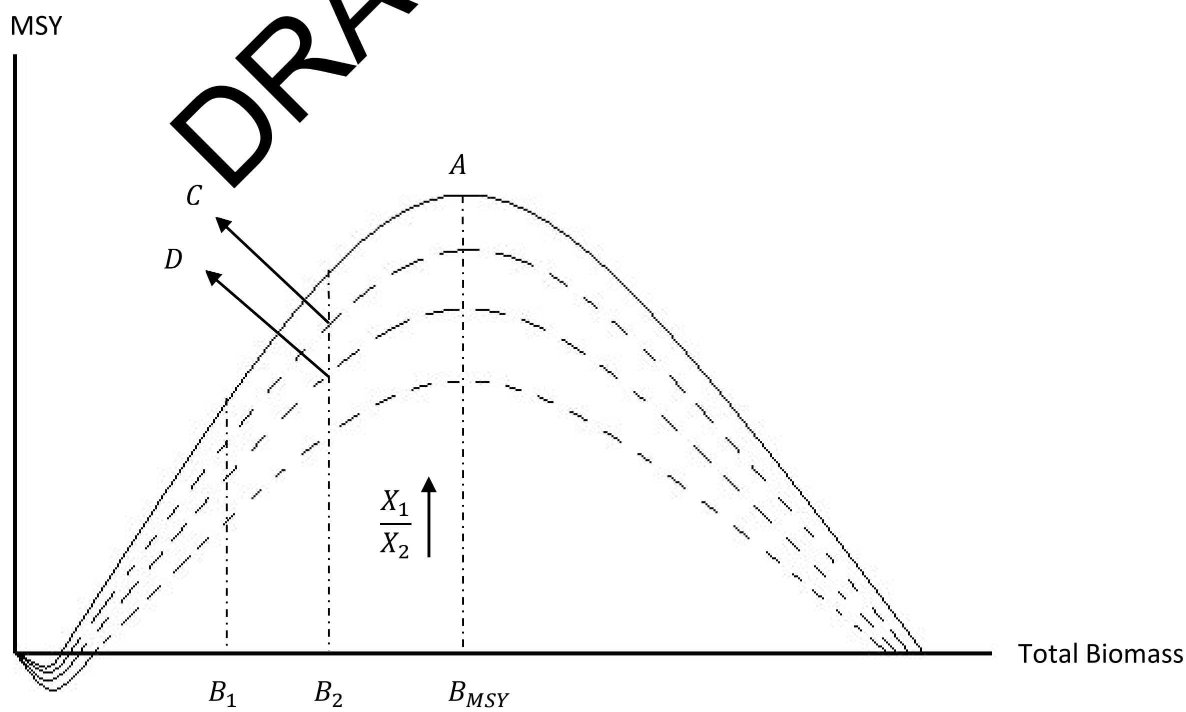

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Figure 2 shows the relationship between growth in fish stocks (in tons) and total fish biomass stock. The MSY under an age-structured model with three cohorts is the point A where the growth in the fish stock is maximized. The growth in the fish stock can also be negative. If the population size is below minimum viable population (the first point where the graph intersects the horizontal axis), the population growth is negative and the extinction of the population is unavoidable. This figure explicitly shows that MSY depends not only on the total biomass level but also on the biomass ratio of each age classes. For instance, at B_1 level of total biomass, different population structures results in different levels of growth in the total biomass. Furthermore, even at a higher total biomass level, the growth rate of total biomass at B_2 may be less than the growth of the total biomass level at B_1 depending on the proportions of young and old mature fish in the population. The point A refers to the MSY level at B_{MSY} under an age-structured model. The point of C and D refer to the total biomass growth levels at B_2 which are less than the maximum growth level at B_2. At a given total biomass level, the higher the ratio of $\frac{X_1}{X_2}$, the higher the total growth of the fish population. Point A refers to the population equilibrium. Even at the same total biomass level, if the ratio of $\frac{X_1}{X_2}$ is less than the level of $\frac{X_1}{X_2}$ at point A, then the total growth of the fish population will be less than the growth at the equilibrium point A. Thus, it is not only important to reach the total biomass level but it is also important to reach the equilibrium population levels for both age group of the fish stock. The constraints below specifies the solution (at the population equilibrium) for X_1 and X_2 at MSY as in Skonhoft et al. (2012):

$$X_1 = s_0 \, R(X_1, X_2),$$

$$X_2 = s_1 \, (1 - f_1) \, X_1 + s_2 \, (1 - f_2) X_2.$$

In the light of the discussions above, the rest of the paper focuses on the catch compositions of fishermen. The effect of per weight harvest of small-scale fishermen on the population growth is lower than the effect of per weight harvest of large-scale fishermen since small-scale fishermen are operating in coastal areas and harvesting old mature fish at a higher rate. This is to say that small-scale fishermen have a higher fishing selectivity than that of larger-scale fishermen. Under different catch compositions of different types of vessels, the question that 'Does initial quota allocation matters?' arises under the major principles for TFC system stated by the European Commission. The reason is that under restrictions such as setting minimum quota levels for small-scale fishermen, there will not be a free trade or perfect transferability for all quotas which means that fishermen may not converge to the pre-determined (target) level

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of quotas after quota trade occurs at the population equilibrium. On the other hand, Ledyard (2009) shows that whatever the initial quota allocation is, fishermen converge to their target quota shares under free trade mechanism. This result is not valid if there is a minimum level of quotas set for small-scale vessels which are not tradable. The European Commission agreed on such a restriction for protecting small-scale fishermen and providing sustainability of employment in the fishing sector. Thus, it is highly expected to be the case that the level of minimum quotas will be set at a higher level of what would it be under free trade environment. Hence, the final quota shares which are expected to be under perfect transferability of quotas will not be observed after the limitations issued on the quota holdings and transferability of quotas. As a result, it can be deduced that final quota levels of large-scale fishermen may not converge to and most probably be less than the target quota levels of them if the restrictions such as minimum quota reservation for small-scale fishermen are issued. This implies that quotas will not be transferred from high marginal cost small-scale fishermen to low marginal cost large-scale fishermen.

The reserved quota ratio for small-scale fishermen is $Rs > 0$. The final total quota level (at some period depending on the cost structure of the fishery) for small-scale fishermen under transferable quotas is zero since quotas will be transferred from high marginal cost small-scale fishermen to low marginal cost large-scale fishermen given that secondary markets are perfect. Then, the impact of fishing is less than the impact of fishing which would be observed under free trade or transferable quota environment as in the previous subsection. In order to exemplify that on Figure 2, suppose that the reserved nontransferable quota ratio for small-scale fishermen is a positive amount. As a result, the ratio of old mature fish harvest to total catch will be higher since small-scale fishermen will hold higher levels of final quotas. Thus, the ratio of the young mature fish population to old mature fish population ($\frac{X_1}{X_2}$) will be higher under restricted transfers than which would be under free trade conditions. In figure 2, point D refers to the population structure under free trade conditions and point C refers to the fish population structure under the TFC system having trade restrictions. As a result, under the same levels of TACs, the increase in total biomass will be higher from point C and the convergence to B_{MSY} will ocur in a shorter time. However, being at B_{MSY} does not guarantee to satisfy MSY harvesting conditions. In order to achieve MSY in a shorter time, fishing mortality of old mature fish should be maximized ($f_{2,t}X_{2,t} = \sum_{i \in N}[(j_i)\alpha_{i,t}TAC_t]$) and fishing mortality of young mature fish ($f_{1,t}X_{1,t} = \sum_{i \in N}[(1 - j_i)\alpha_{i,t}TAC_t]$) should be minimized in each period. That is, the population growth rate or converge rate to the population equilibrium has to be maximized.

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Since small scale fishermen harvest relatively less young mature fish and relatively more old mature fish due to their high selectivity of fishing ($j_i > j_k$ for all $i \in S$ and all $k \in L$), reserving some proportions of the total allowable catch to small scale fishermen and making their quotas nontransferable will be an effective tool both for protecting social welfare and high level of employment and achieving MSY in a shorter time duration. Therefore, protective actions for small-scale fishermen may result in higher levels of total biomass growth at each period and less time required for achieving MSY harvesting conditions.

Result 2: Reserving nontransferable quotas for small-scale fishermen reduces the time needed to achieve MSY and hence sustainable fisheries.

4. Conclusion

TFC and MSY are among the major topics for the recent CFP reform proposals. The European Commission aims to protect small-scale fishing fleets by reserving non-transferable quotas for the sole use of small-scale fishermen while increasing the economic performance by using TFCs as a management system. In this study, the potential effects of this policy is analyzed. The results show that, the policy may be effective not only in protecting social welfare but also in achieving MSY in a shorter time period. Reserving a certain fraction of total quotas for only small-scale fishermen results in a higher level of total biomass growth and hence less time for achieving MSY harvesting conditions since small-scale fishermen have more selective fishing technology than large-scale fishermen. On the other hand, in terms of social welfare, Member States will be able to protect their coastal communities from the undesired results of the TFC system under the mentioned restrictions on the initial allocation and transferability of quotas. These restrictions will also be effective in stabilizing the employment level in the fish catching sector that could be potentially affected by the concentration problem. In conclusion, the promise of TFCs depends on the design of the quota allocation process and the market structure for quotas, which can be transferable, nontransferable for all fishermen or nontransferable only for small scale fishermen. TFCs can be much more effective to achieve sustainable fisheries if a part of national quotas is assigned to small-scale fishermen.

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