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Schemes with an Olympic System Application

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Working paper

Modeling Fishery Management Schemes With an Olympic System Application

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ABSTRACT.

This paper describes methods to model fishery management schemes. In the paper the main emphasis is on simulation models and not to optimum ones. Furthermore, the study in the paper is concentrated around Olympic fishery management systems were the expansion of the Alaskan fishery in the late 20th century is used as a field case. Although the study is concentrated around the Olympic fishery management it can be used as a guideline in modeling efforts of other schemes, such as these that are based on individual transferable quotas or ITQ's.

KEYWORDS. Fisheries, Resources, Time, Management, Modeling.

1. Introduction

Since Gordon's seminal article in 1954 economics has played an important role, at least in the theoretical literature, in discussions of fishery management. Scott's article the following year (Scott, 1955) argued that the "open access" problem is really a failure of "user cost" to play a role in the fishing decision, a notion that was utilized by Clark and Munro (1975), who formally modeled the phenomenon in a capital theory context. The subsequent literature has focused on the development of time paths of harvesting activity that maximize the contribution of a fishery to social welfare. Interactions between dynamics of fish stocks and those who exploit them have been studied at both conceptual and empirical levels. The result is a rich literature on "bioeconomic modeling" that has been extended to include consideration of multiple fish stocks, the valuation of commercial versus recreational activity, and related topics. Once the nature of the "open access" problem was identified, a variety of ways to address it were proposed. It is one thing to suggest that there is an optimum time path of resource exploitation; it is quite another to set up the institutions and incentive structure to put it in place.

Thus, more recent discussion has examined a variety of alternative fishery management strategies, ranging from restricted entry into fisheries (Rettig and Ginter, 1978), taxation schemes (Weitzman, 2001) and various "command and control" options (Kahn, 1995), to establishment of individual harvest rights (Scott, 1988). Indeed an extensive history of experiences with various techniques is being built, accompanied by expressions of frustration with some of the schemes. Among the frustrations, asserted by both theorists and those in the fishing communities themselves, has been a failure to consider the relationships between fishery management and seafood markets.

Aspects of this relationship have been addressed in recent years, however. Some, for example, have highlighted the interdependencies between fishery management policies, or the lack thereof, and the structure of the fishing industry. This has ranged from investigations of whether a monopsonistic buyer of fish can serve as a substitute for government regulation (Clark and Munro, 1980) to whether specific management schemes can lead to changes in market concentration at the processing level (Casey, et al., 1995; Love et al., 1995).

In the early 1990s, following Canada's introduction of individual vessel quotas into the West Coast halibut fishery, which had become a "derby" through the imposition of ever-declining season lengths, it was observed that the form in which halibut was marketed had changed. Prior to the new program, seasons as short as 4 days had generated a "race for the fish" by the fleet and resulted in the delivery of huge volumes of halibut to the processors over a very brief time period. Processors had no choice but to freeze the bulk of the catch.

Under the new individual quota system, there was no such time constraint. Fishermen were able to harvest and deliver their harvest when they perceived market and fishing conditions to be most advantageous to them. Processors found that it was no longer necessary to rely so heavily on freezing and found that they could market halibut in the fresh form during what had become a much longer fishing season. Here was a case, then, of a change in fishery management policies leading to a change in the form in which the product of the regulated fishery was marketed and subsequent increases in the price to fishermen, a phenomenon that had been addressed in a detailed analysis of that fishery thirty years earlier by Crutchfield and Zellner (1962).

The Canadian halibut program, together with its subsequent companion program in Alaska in 1995, sparked considerable interest in the markets-management interface. Wilen and Homans argued in 1992 that, by focusing on the dissipation of resource rents under the assumption of constant (ex-vessel) prices, analysts had overlooked the "marketing losses" from open access fisheries, even those subject to regulation (Wilen and Homans, 1994). Their analysis relies on the assumption that the product of an (optimally) managed fishery commands a higher price than does the product of an open access fishery. For the halibut fishery this assumption was accurate (Herrmann, 1996, 2000)

In a series of articles by individuals who have both academic and fishery management responsibilities, Squires and his colleagues (Squires, 1987, 1994; Squires and Kirkley, 1991; Kirkley and Strand, 1988) considered the problem of regulating a "multiproduct" industry, where the products are, in fact, fish species. They found "limited support...for the traditional bioeconomic model" in the fisheries they studied (Squires, 1987, p.246) because of technical rigidities in the input-output relationships within those fisheries. With production quotas, discarding and other inefficiencies are likely, whether such quotas are at the industry or the individual firm level.

Another case of multiple products from a fishery is that of various fish sizes, or other attributes, from a particular stock. When fishing takes place as part of a "race" (such as occurs under the Olympic system, discussed below), the mix of such attributes may be substantially different than when harvest speed is less critical (such as under an individual quota system). Geen and Nayar (1988), for example, found that introduction of an ITQ system into the Australian Southern Bluefin Tuna fishery would lead to a larger percentage of large fish in the catch, largely due to the premium on large fish in the Japanese sashimi market. The ITQ system, by reducing time pressure, permitted a more measured search and targeting strategy. On the other hand, in the case of the aforementioned Canadian halibut fishery, the mix favored a greater share of small fish after the implementation of the IVQ[1] program than before, a consequence of the attractiveness of the smaller sizes to the market for fresh fish (Casey, et al., 1995). In both cases, the "marketing rents" (Wilen and Homans, 1994) were greater under the individual quota arrangement than under open access conditions, even regulated open access.

Nonetheless, there are some associated costs, not the least of which is "highgrading," in which low-valued fish is discarded so that quota, hold capacity or other quantity restrictions can be met by higher-valued fish (Anderson, 1994; Arnason, 1994). With quota restrictions on the volume of fish available to the individual vessel or fisherman and an eventual limit on season length (whether imposed by stock behavior, regulation, or the market), the decision-maker has an incentive to discard fish that do not meet the desired criteria, in the hope of catching substitutes that do. As indicated earlier, this is an issue identified by Squires and colleagues in their analyses of multi-species fisheries.

The multiple product issue has, then, been discussed largely in terms of multiple species and different attributes of individual fish within a given species. A multiple product issue has received little attention, at least from an analytical perspective. With multiproduct issue in this context we mean alternative products from a given animal, irrespective of attributes. What differentiates this issue from the multiple attribute questions is that sorting by or searching for those attributes is not part of the fishing decision. Consider the case of a vessel with on-board processing equipment that can be used for two or more products from a given species (or, perhaps, from several species) and where the decision of which product to produce from a given animal is independent of that animal's size. The most obvious but, by no means the only, example would be the case where all members of the catchable population have approximately the same size. The product mix, in this case, will depend upon processing costs and prices of the alternative products. The interesting economic question is whether alternative management structures yield different results with respect to product mix and total harvest. A related question has to do with whether

[1]Under the Canadian scheme, the quota attached to the vessel (V), rather than the individual.

different management regimes have an impact on the economic contributions of such a fishery.

An often-heard description of fisheries is that they are price takers. This is due to natural fluctuations, the fishermen have to harvest when fish is available (in the fishing seasons for example), and consequently accept the prices offered. The circumstances and the behavior derived thereof, characterizes several important groundfish industries Among them is the Alaska Pollock fishery, where an important component of the fleet both harvests Pollock and processes them on board into several products, using modern processing equipment. In their study, Arnarson and Jensson (2003) simulated this behavior using a model of a factory trawler. The simulation was furnished with random catch generator that provided unexpected quantities, as we can expect in the natural environment. The unforeseen happenings will alter the agent's economic space or window of opportunity. In order to optimize his economic process, the agent will rearrange the use of the resources available to him in the process (he is a price taker). Doing so he will increase or decrease the economic output at each decision point in time. This behavior can result in a range of assortment of products that are specially designed to suit different market segments.

The implementation of the sales market dimension in to bioeconomic models was introduced by Arnarson and Jensson (2004). The study showed that determination of the optimal quota for a given fishery could be done independently from deciding the total effort and the thus, the rate of harvest from that given stock. The optimum quota for each unit was dependent on the market prices and the capital stock. The study also revealed that there could exist relatively large discrepancies between revenues, when calculated from the point of individual agent and when measured from view of legislators who are interested in optimizing the industry as a whole. The following study focuses solely on the behavior of economic agents and is not an attempt to optimize a fishing industry. The results from simulation model of this type and can however be used as an input in optimizing models as demonstrated by Arnarson and Jensson (2004).

The objective of this paper is to provide an application that can be used as platform or guidance to map fishing industries. As argued afore, the biological part of the bio-economic equation can be handled separately and will not be included in following analyses, the focus will be solely on the economic aspect of the problem domain.

The biological part we leave to the biologists and specialists on fish stock assessments.

2. An Individual Quota-, or Olympic System Fishery Management?

Since the extension of the fisheries economic zones in middle of the seventies the economic literature as well a practical fishery management has been occupied with determining what is the most efficient fishery management scheme. The debate has basically evolved around the concept of individual transferable quotas versus open access management, or the Olympic system[2]. Although there exists a disagreement, the majorities of economist as well as agents of management schemes are in favor of the ITQ's. In this context the ITQ's has often been used as a synonym for property rights. The property rights or ownerships as it is also named, has been used as a metaphor[3] for higher economic efficiency within management systems of natural resources. They phrase however, property rights or ownership, does not have any economic meaning or dimension, although we do not doubt that it has a legal dimension.

Arnarson (2004) and (Arnarson and Jensson, 2003) show that the possible difference in economic efficiency between processes that run under the ITQ management system and the Olympic system, has its cause in the value of the time resource. If we use the Olympic system as an example then, at each decision point in time the fish resource is unlimited for the participants until the TAC's is reached and the process comes to a halt. Unlimited access to one resource makes it relatively cheaper[4] than other resources that are necessary to maintain and run the economic process. Obviously, if the behavior of agents changes due to relative change in prices of the resources, one or more resource in that process has to be substitutes. A change in the input mix of the resource will yield a different output or commodity. This requires in turn, that there is demand in the sales markets for more than one product that the agents can produce by mixing their resources. In this paper we will for the shake of clarity assume that there are only two resources that can act as substitutes, the raw material (fish stock) and the time resource.

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[2] We assume that all fishery management scheme addressed limits their outtake from the fishing stocks by imposing TAC's.
[3] For more discussion about metaphors in economics see for example McCloskey (1986).
[4] We distinct between values within the economic process in time and market values.

In groundfish fisheries each species can be literately produced into manifold of products i.e., salted, dried, frozen, fresh. These preservation types can be in various forms; filets, whole, headed and gutted, and wrapped in different packaging due to difference in demand from different market segments. Consequently, each product of this assorted portfolio of products has different prices attached, production costs as well as sales prices. As a rule of thumb, the prices of these products are usually calibrated by the time used in the production. Thus, the value added products are usually those that need more time to go through the processing lines. To simplify matters, the portfolio of products from groundfish specie can be regarded as a scale, where the time consuming in production and value added products are at the one end and the cheaper but fast producing products are at the other. Given unlimited access to a raw material the price of it in the economic process will be relatively low and the value of time relatively high. In a situation like that we would expect the economic agent to spare the valuable time as much as possible and choose products that are relatively low priced and fast in production.

The economic space (window of economic opportunities) of an economic agent will always be bounded, if not by the time resource then by other resources (raw material, labor, capital etc.), and furthermore all resources in an economic process in time are interdependent. The change in one resource in a process will result in change of the shape of the economic space and therefore the economic outcome of that same process (Arnarson, 2004). Thus change in capacity (capital) input of a fleet will change economic output as illuminated in Figure 1. The model in Figure 1 assumes that the fishery is under ITQ fishery management system. TAC is fixed and same for all capacity levels. This means that as the capacity increases the ITQ per unit decreases.

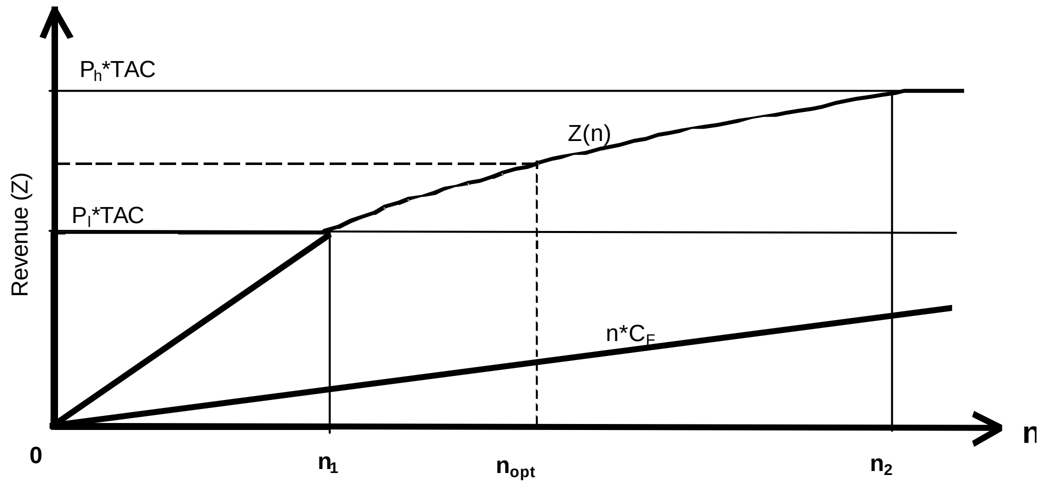

Figure 1. Gross Revenue for an Economic Process. P_h: Highest price, P_l: Lowest price, n: Number of units, n_1: Capacity limit of the industry (fleet) when producing the fastest products, n_2: Capacity limit of the industry when producing the slowest products, n_{opt}: Optimal number of units, C_F: Cost per unit, Z: Revenue, TAC: Total allowable catch. Adopted from Arnarson and Jensson (2004).

If the quota per unit is set at the capacity peak of the industry n_C or more (the number to the left of n_1 on Figure 1), the cost of the raw material will be low and consequently the value of the time resource will be relatively high. At very high quota levels per unit, the interval 0-n_1 on Figure 1, the Z(n) is linear. At this interval the value of the raw material is very low due to relatively high abundance in the process, and value of time resource is high resulting in production of fast but low priced products. As the number of vessels increases and thus, quota per vessel decreases, the abundance of the time resource in the economic process becomes relatively higher compared to the other resources[5], and thus, relatively lesser valuable. Increasing the number of units enough we will reach the point n_1, were the production produces only the most valuable products[6]. Somewhere between n_1 and n_2 lies n_{opt}, or the optimal size of the industry. It should be noticed that the point n_{opt} on Figure 1 is included for illustrative purposes only, as mentioned afore, the objective of the paper is simulation of fishing industries but not to optimize. The concave form of the net revenue curve between n_1 and n_2 has been known in the literature by the metaphor, *the law of diminishing* returns, but as demonstrated in Arnarson (2004) and Arnarson and Jensson (2003),

[5] Here, we have to keep in mind that at each decision point in time the sales prices are fixed for the economic agent. He cannot have any influence on sales prices at all but he can shuffle his use of resources in order to maximize his output.
[6] Another way of explaining the same thing is a rule of thumb used in the Icelandic fishing industry. When excess raw material, one should produce what gives him highest revenue per time unit (Olympic case). When time is abundant, one should produce what gives highest revenue per unit raw material (ITQ).

this concavity is due to increasing (or decreasing as we go from left to right on Figure 1) cost of the time resource.

Within the Olympic management system the agents, as mentioned afore, will harvest as much possible in shortest possible time. This equals the situations that can be found along the interval $n>0$ and $n<n_1$ on Figure 1. Along this interval the abundance of raw material is excessive (enough at one point (n_1) which is exactly the same situation as in the Olympic system case. In an industry that is under the Olympic fishery management, the abundance of raw material (the fish resource) is in excess (or unlimited) at each decision point in time. At each point in time the agents can theoretically and in practice fish more. It will remain so until the ruler (the fishery manager(s)) brings the fishery to a halt when it reaches the TAC decided before the fishery started. When simulating the behavior of agents under the Olympic fishery management system we can assume that the cost of the time resource is extreme high and constant as represented by the linear form of the curve Z(n) in the interval 0-n_1 (Figure 1). The value of the time resource within the Olympic fishery management system can be regarded as a constant (linear) and ignored as a variable when simulating the Olympic system. Arnarson and Johnston (1992) simulated successfully with an aid of linear programming engine, the Newfoundland fishing industry without including the time resource as a variable in their analyses. If however, the value of the time resource is relaxed enough relatively to the other resources, as is the case in the interval n_1-n_2 in Figure 1, the value of the time resource has to be included in the optimizing effort. A method to modeling fishery management schemes were the time resource is included as a variable, is portrayed by Arnarson and Jensson (2003). The following application is a simulation assumed to run under the Olympic fishery management system, and ignores the value of the time resource.

The cause to the possible difference between the Olympic-, and the ITQ system lies in the cost of the time resource (Arnarson, 2004). By introducing ownership in an economic process the ruler has possibly reduced the value of the time resource for the agents participating in the process. The reduction in the value of the time resource is dependent on that one or more of the resources of the process are substitutes and that the process is at the concave interval, n1-n2 in Figure 1.

3. Mapping the Economic Space of the Alaskan Groundfish Fishery

The Americanization of the Alaskan groundfish industry started in the wake of the extension of the economic exclusive zones in the 1970's. At that time the groundfish resources of Alaska were harvested by none-American fishing fleets from Japan, Poland and Korea. Through legislature (Magnusson Act) the fishery was Americanized in a shorter time than expected or in late 1980's the transfer of the "ownership" was complete. In 1990 the harvesting capacity of the American factory trawler fleet was sufficient enough to fish up the Alaska Pollock quota (TAC) in Gulf of Alaska in few weeks which left the shore based processing facilities without a raw material[7] for the rest of the year. This caused an outcry from the shore-based processors that mostly where located in Gulf of Alaska and dependent on the resources from the same area. The shore-based processors then demanded that a considerable share of the resources should be allocated to them, which of course their counterparts, the owners of the factory trawlers did oppose[8].

The choice of problem domain in this paper was selected in cooperation with the North Pacific Fishery Management Council, NPFMC. The NPFMC was interested in to be able to analyze results of implementing various limitations on the Alaskan fishing industry. The simulation model was to run under the Olympic fishery management system. Along with the impacts on allocating the fishery in to inshore and offshore sector, the council was interested in more detailed behavior of the economic agents. They needed information on the economic outcome of different breakdown of the resource allocations, broken down by vessel categories, in what areas they are likely to fish, fishing gears, by-catch rates[9] etc.

Obviously, the Alaskan fishing industry is too big to simulate each and single agent. To keep the exercise under manageable size the agents were accumulated in to categories according to similarity in the economic space. Given the similar economic space, it is anticipated that the agents will react similar way to changes that occur in

[7] The shore based production facilities are dependent on catcher boats to bring in the raw material. The factory trawler has both processes, harvesting and processing, within the same unit.

[8] For further description of the Alaskan fishery around 1990's see for example Arnarson and Trondsen (1989).

[9] By-catch is the amount of other species caught when targeting a specific specie. When targeting Alaska Pollock for example, there could be considerable by-catches of Cod and Halibut.

their operating environment, forcedly by the management or due to natural fluctuations. The agents of this economic process in time are described by their capability to assign attributes to raw material (manufacture products) and are categorized accordingly. Based on these attributes we can divide the Alaskan fishery roughly in to five types of harvesting and processing categories.

1. Motherships and catcher boats with trawls. This category includes some of the biggest vessels in the Alaskan fishery. Onboard the motherships there are usually most methods of fish processing, filleting, H&G[10], surimi, meal and oil etc. The size (investment) of these vessels makes them ill suited to use lesser effective fishing gears such as longlines, gillnets and pots. Some of them are without harvesting capacities and relay on catcher boats to feed the production lines, other have harvesting capacity but need additional supplies from the catcher boats. Catcher boats are often independent and sell their catches to the motherships, as the shore-based catchers do to the shore-based plants. The catcher boats in this category are for the most without a fish hold[11]. The decision on how much to fish, where and when is usually in hands of the operator of the mothership. The catcher boats without a fish hold are therefore included within the economic space of this category.

2. Motherships and catcher boats with pots. The motherships in this group traditionally fish near shore and are targeting value added products such as, crabs, halibut, salmon and rows. The supplying catcher boats are typically small, fishing with pots and not suited for longer trips. This category of operation is similar to the shore based one with the exception of the motherships ability to move along the coast as the fish migrates. As for the motherships with trawl, the harvesting decisions are in the hands operator of the mothership.

3. Factory trawlers. This category has the ability to harvest and process. The bigger vessels in this category have capability to produce the most of the groundfish products, surimi, fillets and meal/oil. Although it is not done in this paper it is natural to divide this group in to two, vessels with surimi production capability and vessels

[10] Headed and gutted products.

[11] These boats hand the Cod end (the end of the trawl that contains the fish) over to the motherships and do therefore not need to haul the fish onboard. The catcher boats that are harvesting for shore-based plants do not have this opportunity.

without (fillet trawlers), due to the difference in the economic space of these two groups.

4. Shore based fish processing plants with catcher boats. The shore based fish plants are not restricted by operational space as the vessels. The plants will therefore have capability to produce almost all feasible types of products. The shore-based plants are dependent on catcher boat with fish hold capacity. As for the motherships, the decision on landings is assumed be to be in the hands of the plant operator.

5. Factory longliners. These vessels will only use longlines in their fishing operation and basically target Cod and produce H&G products.

As mentioned above the economic space of the agents (categories) are mapped according to the their ability to add attributes to the raw material. To add a specific attribute will require a special capability of the agent (category). If we take surimi as an example, the production facilities have to be within a short range from the harvesting spot, because the fish has to be processed within two days (from the time of harvest). In order to meet profitability requirements the surimi production has to be of a certain minimum size (economic of scale), which calls for accordingly equally sizable investments. This in turn requires equally considerable throughput of raw material that requires fish stock which abundance and behavior that has the potential to yield the necessary quantity to the process. The only stock in Alaska to meet this requirements is the Alaska Pollock and seasonally the Cod, and the only fishing gear with necessary effectiveness is the midwater trawl and in short seasons, the bottom trawl. An agent that is targeting Alaska Pollock with midwater trawl and producing surimi in Gulf of Alaska will most likely yield a different cost structure than identical operation in the Bering Sea. Difference in catch rates for various fish stocks and areas will also contribute to the diversity in attributes. A surimi product, harvested and produced in Gulf of Alaska may have a different cost structure than product processed by identical operation in the Bering Sea. An agent operating in one area may therefore behave different from an agent operating in another. This is so because their economic windows of opportunity or the economic space differ.

The economic space of an agent does not solely consist of cost structures but also on how the same space is demarked. Conveniently, we can divide these frontiers in to three groups, technical-, social-, and market possibility production frontiers. Figure

5, gives an overview of how the economic space of agents in the Alaskan fishing industry is mapped.

Social-, and Market Possibility Production Frontiers	**Inshore TAC, Offshore TAC, Sales Prices**	Allocations, market prices, by-catches, seasonal restrictions etc.
Economic Space of the Agent's in the Alaskan Fishing Industry	**Products**	Filets, H&G, surimi, rows, meal, oil etc.
	Areas	Midwater trawl, bottom trawl, longlines, pots, gillnets etc.
	Fishing Gears	Area 1..n in Bering Sea, Area 1..n in Gulf of Alaska etc.
	Species	Cod, Alaska Pollock, Halibut, Blackcod etc.
Technical Possibility Production Frontiers	**Categories**	Factory trawlers, motherships, shore based processors etc.

Table 1. Mapping the Economic Space of the Alaskan Fisheries.

In the case of Alaska, the management area is divided in to two regions, Gulf of Alaska and the Bering Sea. Each region is divided in to smaller management areas. An area within the Gulf of Alaska for example, can have a number of economic cost generating attributes attached to it. Attributes as, allocations, restriction on the harvesting operations, distance to nearest harbor, catch rates, whether it is a spawning ground or not, etc. The same applies to the fishing gear and the target species chosen. Different fishing gear have different catch rates, by-catch rates[12] and require different physical space onboard the vessels, etc. Different species can be found in various quantity and abundance in time and space in addition to a difference in size and other biological properties that can have impact on the economic space.

4. The Decision Engine

When using the linear programming tool as a decision engine in simulations of economic agents under the Olympic system, the last run of the model will usually be

[12] Each target species has a by-catch attached to it. If a vessel is fishing for Cod, for example, it will get a by-catch of other species, Pollock, Halibut etc. This is especially important with regards to prohibited species. If a certain quantity of prohibited specie (Halibut for instance) in the Cod fishery in Gulf of Alaska is reach, the management will close the fishery down, even though the total TAC for Cod in that area has not been reached.

in “error”. As mentioned afore, within the Olympic system there is excess raw material in the process at each decision point in time and thus, time costs very high. If the last time interval in the simulation is large relatively to the raw material, the decision engine will use more time in optimizing the process, and the behavior will be more in way we would expect within the ITQ management system. The size of the error of this “flaw” of the method can be reduced by shorting down the time periods, especially at the end of each run.

The decision engine (agent) in the following model is a linear programming (LP) tool. The resources are allocated (TAC’s) to each sector of the industry (inshore, offshore). The model is run stepwise through time (in this case on monthly basis), i.e., a LP optimizing is run for each category at each point in time in the economic process. The accumulated results from one point in time are carried through to the next point (see Figure 1).

Indices:

a: area (Bering Sea, Gulf of Alaska,....)
g: gear (trawl, longlines,.....)
f, s: fish species (Pollock, Cod,.....)
p: product (fillet, surimi,...)

Indices f and s are both used for fish species. However, in the following, f can be understood as the targeted fish species, while s is the species, caught[13].

Decision Variables:

X_{sp}: Quantity of product *p*, produced from the fish species *s*.
Y_{fga}: Quantity caught of target species *f* using fishing gear *g* in area *a*.

Coefficients:

S_{sp}: Net selling price for product *p*, species *s*, i.e., sales price minus product dependent variable costs.

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[13] When fishing for Cod for example, there could be considerable by-catches of other species like Halibut and Black Cod.

VC_{fga}: Operational dependent variable costs when fishing for f, with fishing gear g, in area a.

CR_{fga}: Catch rate when fishing with fishing for species *f,* with fishing gear *g,* in area *a* (tons pr. day).

BC_{sfga}: By-catch of species s (%), when fishing for target species f, with fishing gear g, in area a.

TAC_{sa}: Total allowable catch of species s in area a.

FD: Available fishing days for the rest of the season.

W_{sp}: Labor requirement coefficient for product p, species s (man hours pr. ton).

R_{sp}: Machine (i.e. freezing capacity of the equipment, machine hours pr. ton).

L: Available labor for use in the production lines (man hours).

M: Available machine capacity for use in the production lines(machine hours).

The Engine:

The objective is to maximize the net profit at each point in time, for each category (agent):

$$MAX \sum_s \sum_p S_{sp} * X_{sp} - \sum_f \sum_g \sum_a TC_{fga} \tag{5.1}$$

Subject to (frontiers):

Restriction on how much quantity it is possible to fish and produce from each stock,

$$\sum_f \sum_g BC_{sfga} * Y_{fga} \leq TAC_{sa} \forall s, a \tag{5.2}$$

Constraints on available fishing time,

$$\sum_f \sum_g \sum_a \frac{Y_{fga}}{CR_{fga}} \leq FD \tag{5.3}$$

Constraints on by-catch for each region and area,

$$\sum_p X_{sp} \leq \sum_f \sum_g \sum_a BC_{sfga} * Y_{fga} \forall s \tag{5.4}$$

Labor frontier. Available labor force for the production,

$$\sum_s \sum_p W_{sp} * X_{sp} \leq L \tag{5.5}$$

Constraints on available machine hours,

$$\sum_s \sum_p W_{sp} * X_{sp} \leq M \tag{5.6}$$

and

$$X_{sp}, Y_{fga} \geq 0 \quad 5.7$$

This model type is solved for each category of agents, in order to simulate a rational behavior; i.e. how they would respond to a given allocation of TAC by choosing target species (Yfga), fishing gear, fishing areas, and by choosing a product mix for each species caught (Xsp). The computer implementation of the model was slightly changed to make the programming work easier. The main difference is that instead of two sets of variables, Xsp and Yfga, only one set was used.

The model described above is solely to simulate the Olympic system fishery management system. The model can however, easily be altered to simulate all management schemes by implementing addition for the ITQ case as for each category of economic agents as described by Arnarson and Jenson (2003).

5. A Simulation Example and a Closing Discussion of Modeling the Olympic Case

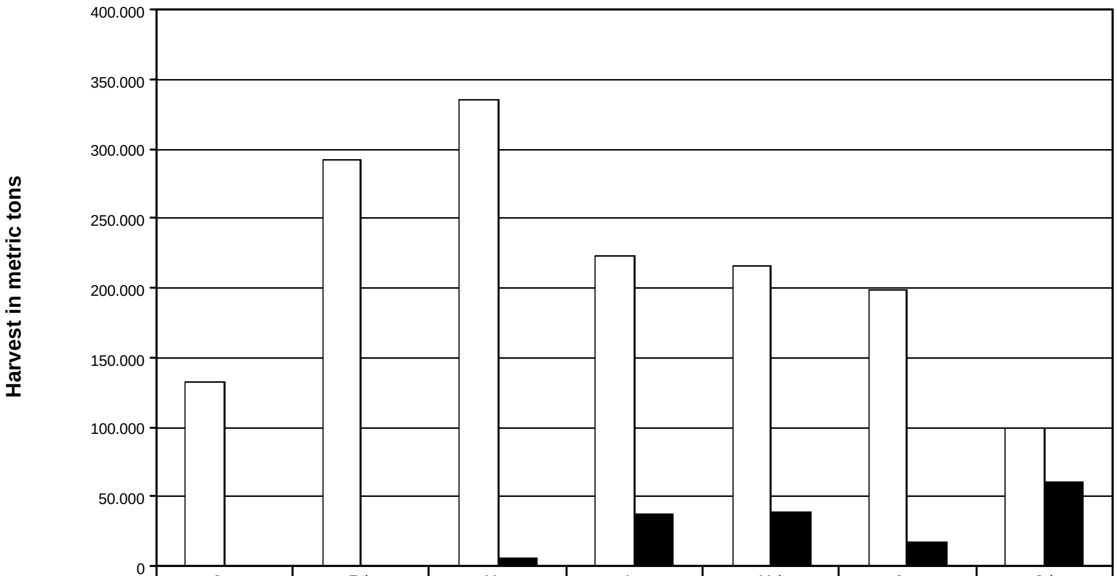
As mentioned afore, to sample data and run full-scale analyses of the Alaskan fishing industry is not the objective of this exercise. The theory and logical framework is already in place and an extensive data collection will doubtfully contribute anything new or alter that framework. We leave the full-scale exercise to fishery managers and others that can benefit from running full-scale simulations under different management schemes. Furthermore, the use of the linear programming tool as a decision engine and a more detailed description of the data input are described in more detail in Arnarson and Johnston (1992) and Arnarson and Jensson (2003). The following numerical example is purely for illustrational purposes and is in no way an attempt to act as management guidance for the management of the Alaska fisheries.

The model was used to simulate the expected catches in Gulf of Alaska and the Bering for the year 1991. The simulation in this case was run for only for the offshore allocation. In the simulation only two types of categories were used, motherships and factory trawlers[14], two types of fish species, Cod and Pollock, and could choose between two areas, Gulf of Alaska and Bering Sea). Furthermore, only two types of

[14] These two categories where responsible for nearly all groundfish landings around the 1990's in the Bering Sea.

fishing gear were allowed, bottom or midwater trawl and the products available to the agents to produce were surimi, fillets or throw[15]. As discussed in Section 2, the characteristic of agent operating under the Olympic management system is that they usually face very high price on the time resource and comparatively very low on other resources. We will therefore expect the agents to harvest and produce as much possible in shortest available time. Due to technical limitations the agents will not be able to respond to changes in the environment by increasing other resources, such as labor, at least not for a shorter time period's. The vessels for example will only be able to accommodate limited number of workers and the production lines in general, onshore or offshore, will have limited capacity. There are therefore basically two resources that can act as substitutes in the economic process, time and fish stocks (raw material).

Figure 3 shows the simulated harvesting rate for the two species Alaska Pollock and Cod. The annual TAC for Alaska Pollock allocated to the fleet in this example is 1.500 million metric tons and 160 thousand metric tons for Cod ("simulation for the year 1992").



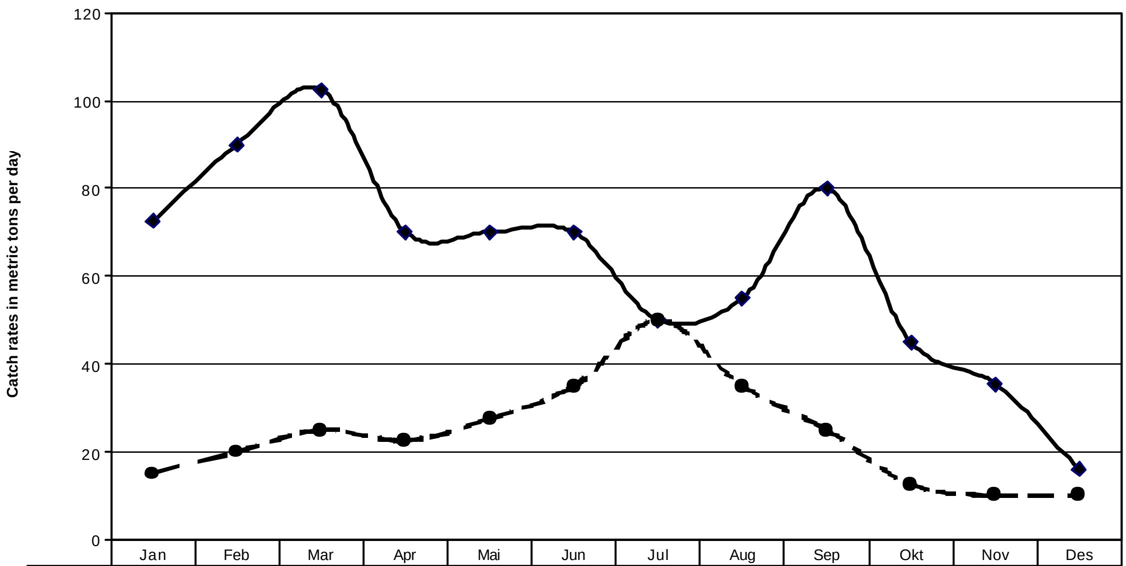
	Jan	Feb	Mar	Apr	Mai	Jun	Jul
Alaska Pollock	133.261	292.568	335.615	224.031	216.421	198.906	99.199
Cod	0	546	5.837	37.384	38.761	17.475	59.998

Figure 2. Simulated results. Harvesting rate in the Berings Sea and Gulf of Alaska. Simulated for the year 1992.

[15] When targeting Alaska Pollock and producing surimi for example, the catch can include a considerable amount of by-catch of other species. In cases, it can be profitable to throw this by-catch overboard instead of letting it delay the more profitable surimi production.

The simulation predicts that the fleet has harvested its annual TAC, in both Alaska Pollock and Cod, already in July. The simulations does not start to target Cod until the catch rates are well above 20 metric tons a day or in Mars, in Figure 3. The decline in the Cod harvest is due to shift from the Bering Sea to Gulf of Alaska in June. The results from the simulations are as expected, both when it comes to expectations before the exercise and the historical outcome. Indeed, this is what we can expect from an economic process with a relatively high valued time resource. Given the theoretical framework and the results from the simulation above it is legitimate to deduct: Why bother with the Olympic fishery management system at all, the economic output is always going to be the worst possible anyway? There are number of reasons for this and here we will only name few of them. The most common is that there exists a political agreement in the society to keep the Olympic fishery management system. In that case, which has been the case with the Alaskan groundfish industry, it is of interests to analyze the impact of various regulations on the industry.

In 1992, the NPFMC divided the allocations in the Alaskan groundfish industry between two seasons. The rational for this allocation between seasons was to get more spreading in landings in order to improve the economic efficiency of the industry. If we assume that the catch rates are constant over the year we would expect to get two identical Figures for each season, or January-Mars and July-September. The fish migrations are however differ from season to season and actually in most cases they will fluctuate on daily basis. The monthly variations in monthly catch rates are illustrated in Figure 3.



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des
AP	72,5	90	102,5	70	70	70	50	55	80	45	35,5	16
AC	15	20	25	22,5	27,5	35	50	35	25	12,5	10	10

Figure 3. Average catch rates in trawl in Gulf of Alaska and Berings Sea. In metric tons, 1984-1989. AP: Alaska Pollock. AC: Alaska Cod. Source: NFMS databases.

As we can see from Figure 3, there is large variation in catch rates throughout the year, for both species, the Alaska Cod and Alaska Pollock. Clearly, the availability of raw material will be different in Mars than in July. The raw material input is therefore not constant over the year and allocation of the TAC between one or more seasons can therefore have considerable impact on the economic behavior of the implicated process. When taking in to account that there are number of different species that can be produced in to many different products which sales prices can also have a seasonal variations, the possible impacts of different allocation of the TAC are way beyond calculation of a human mind. In those situations, to have a realistic simulation model is of considerable value to have as and aid in the legislation and implementation process.

Although the ITQ management system can potentially yield a better economic results, there are cases were at least theoretically, the Olympic system will yield similar results. As discussed in Section 2, the difference between the ITQ system and the Olympic has its cause in the value of the time resource. If the value of the time resource within an ITQ fishery is relatively high, the economic outcome can be the same as within the Olympic system. An example of such a fishery is the Capelin fisheries of the North-Atlantic. The migration behavior of the Capelin is not well understood. The Capelin can suddenly appear in catchable quantities and equally suddenly disappear. Therefore, the vessels have to harvest as much as possible at every decision point in time. The value of time in the process is therefore relatively high and the value of the raw material (the Capelin stock) relatively low. The Capelin is for the most harvested by highly efficient purse seiners and the shore based facilities produce in to one product only from the stock, fishmeal and its byproduct fish oil. In the purse seine fishery for capelin there exists no substitution of resources. There are therefore at least two reasons for the economic agents of the Capelin fisheries in the North-Atlantic to behave as represented by the interval 0-n1 on Figure 1. If Figure 1 represented the Capelin fishery the Z(n) would be linear in all cases. Hence, to introduce ITQ's in that particular fishery would not yield any increment in the economic efficiency of that industry.

So far, we have only discussed the situation were the agents are having the possibility of shuffling the time-, and the raw material resource. Usually, the agents will have the possibility of shuffling number of resources within the same economic process as described in Arnarson (2004). In the analyses and the discussion only two resources are included. Adding more resource variables to the analyses would make it to complicated and tedious to present the line of argument. Let us now shift the focus on the economic process, zoom out and include the investments or capital needed to run the process. By adding the capital we shift the focus from analyzing the processes "short run" to include what is usually termed as a "long run"[16] process. As before, we are operating under the Olympic system and can therefore treat the time variable as constant the analyses or in other words; at each decision point in time the raw material is abundant. Let us further assume that the capital and the rest of the resources necessary to run the process are substitutes. In the case of expensive (scare's) capital the agents will strive to use more of the other resources. If their economic space were shaped in certain way the agents would for example use relatively more of manpower than capital. Let us scrutinize this in light of what happened in the Alaskan Groundfish industry from the extension of the economic zone in 1977 to 1992. In the beginning the American finance institutions and investors were sluggish to finance groundfish operations in Alaska. This was basically due to the collapse of the Alaskan crab fishery in the middle of the 1970's that lead to mass bankruptcies and had devastating economic consequences for the

[16] The terms "short run" and "long run" are usually associated with Alfred Marshall and time in economics. As argued in Arnarson (2004) these terms and Marshall's analyses have little to do with the time resource in economics. The "long term" is simply to telescope from the "short term", or change focus.

society as a whole. The price of capital for the “new” groundfish industry was therefore very high. This was though to change, first through Japanese and South Koreans that had been fishing in these waters for decades and wanted to secure their future access to the resources within the USA’s EEZ. Later, Norwegian finance institutions came in to the arena offering finances of highly efficient and sophisticated vessels that not surprisingly were build or converted at Norwegian shipyards (Arnarson and Trondsen. 1998). With a relatively high value of the time resource and relatively low on fish stocks and capital the fishery was bound to go in one direction, towards over-capitalization and bankruptcies, as the history has proven to be the case. This raises an important question: Why did the rational agents of the Alaskan fishery process continue to invest and participate in the fishery when it was evident that most of them would be bankrupt in a foreseeable future? Here, the explanation lies in how the agent focus on the economic process as described in Arnarson (2004). At each decision point in time an agent within the economic process will allocate resources that are in his possession according to the shape of his economic space. His economic space is demarked by factors and variables that he can have an impact on. A rational economic agent will not act up on what might be the best for the society, simply because he cannot possibly, at the decision moment in time, have any impact there on. The economic space of a sole owner (legislator or a ruler) may be different shaped than the individuals participating in the fishery. Hence, the behavior (economic optimum) of a legislator that has control over the whole economic process may differ from that of an agent within that same process, as demonstrated in Arnarson and Jensson (2004).

In general, the economic responsibility of authorities in a society is to lower the costs were it is possible (Eggertsson, 1988). In many cases this can be achieved by introducing ITQ’s and lower the time costs relatively to other resource costs of the same process, as was done in the Alaskan Halibut fishery case mentioned in the introduction, or it can be done by relatively lower other costs in the process.

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