Cooperation on Stocks Recover

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Abstract **- The study of cooperation shows that often it brings gains to the agents. In this study it is shown that cooperation is very interesting when exploiting marine live resources. Several kinds of models have been used to show the advantages of cooperation in fisheries (see Munro, 2002; Miller and Munro, 2002; Clark, 1980; or Levhari and Mirman, 1980, for example). In this study, a general model for fisheries is presented and a Cournot-Nash model supported on the variable fishing effort is introduced, both showing that cooperation is useful.**

Keywords— *Fisheries, Cooperation, Cournot-Nash model, Stocks recover.*

1. Introduction

The study of commons is very important when intending to analyze the consequences of human behavior in the exploitation of Earth resources. Hardin's publication of "the tragedy of the commons" (Hardin, 1968) was a reference for the problems that traditionally occur in the natural resources area. The essence of the problem is that resources are over-exploited because each agent aims to have the maximum benefits in line with the generalized selfish human behavior.

Hardin proposed several measures intending to preserve resources from over-exploitation. He proposed, for example, the privatization of resources or the implementation of coercive measures. Of course it is important to implement several rules to avoid tragedies and the cooperation among agents is an important instrument to reach this aim. This means that if there is cooperation – among all the agents who exploit the resource and the agents who rule or coordinate resources exploitation - the given resource is prone to be well managed, to be well regulated and to be well preserved. This may allow higher prices in the market for a given resource and higher levels of rents for fishers through low catches -or a reduced exploitation of the resource, whichever it is.

This paper intends to discuss the advantages of cooperation and how cooperation and regulation may contribute to have high levels of stocks and to have high rents for fishers. After giving an overview, showing why cooperation seems to be important to bring up good results to fishing common pools, a presentation of the bio-economic modeling, as it has been presented traditionally, is outlined. Then, a Cournot-Nash model is presented to explain the competing agents' behavior and the role of cooperation in fisheries. It is possible to see that cooperation brings up procedures that allow the preservation of species and stocks recover. Finally, some concluding remarks are over lighted from the study.

2. The cooperation as an interesting way to manage resources

In order to find out solutions to the problem of resource management, cooperation has been seen as an interesting way to reach good results in the exploitation of the commons. Some interesting patterns of human cooperation are exemplified in the literature on institutions for managing the commons (Richerson, Boyd and Paccioti, 2002). Several authors have been studying cooperation on fishing area, as well. It is the case of Gronbaek (2000), who studies a cooperative and a non-cooperative solution in the fishing field and formalizes mathematically a sustainable cooperative solution. Munro (2002) presents, himself, some interesting cases of cooperation on fishing area. Miller and Munro (2002) show that, in general, cooperation is important and that non-cooperation in fisheries usually leads to the overexploitation of the resources.

Clark (1980) and Levhari and Mirman (1980) have studied non-cooperative fishing games. Their studies are supported in different hypotheses and methodologies but they reach similar conclusions. They show that if each country tries to maximize its own welfare, taking into account the actions of the other country, a long term equilibrium can be achieved. This equilibrium will guarantee the

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maximization of the present value of the net economic revenue from the fishery over time and will keep the renewable resource stock at the optimal steady state biomass. Both papers show that the common bionomic equilibrium will occur at a lower stock than the one that would be optimal if the two countries form a cooperative venture (see Hang, 2003).

Clark (1980) uses a linear control model to describe fisheries confined to the EEZ - European Economic Zone - waters of a single coastal state and then he assumes that there are two players in the game, sharing the fisheries of a single fish stock. Both trying to exploit the maximum possible part of the stock because they have no restrictions to access it. Consequently, the exploitation by each one of the agents will affect the available part of the stock that will remain in the sea and this will affect the amount of fish that its competitor will have available. Clark shows that non-cooperative feedback equilibrium is discontinuous in the control variable -fishing effort- and that only the most efficient country harvests in the equilibrium (see Hang, 2003).

Levhari and Mirman (1980) use a Cournot model to compare the competitive and the collusion solutions to identify the advantages of cooperation in resources exploitation. They show that the Cournot-Nash equilibrium leads to greater consumption as a function of the size of the fish population and to a smaller steady state consumption (see Hang, 2003). It is interesting to evidence that this methodological approach, which is not much used as the dynamic games proposal of Clark and followers, is rehabilitated in this paper. The reasons will be presented in this paper.

The conservation of natural resources is an important issue that is relevant to study. Besides, when some agents propose themselves not to exploit a resource because they are worried with resources preservation, if one agent considers that there is an opportunity to gain advantages to exploit the resources that another agent has left and he does it, the tragedy may come. The agent that is concerned about the future has lost the rents for not exploiting the resource and, as a consequence, the other agent has won the short run rents for exploiting it.

This problem represents very well the traditional formal issue "Dilemma of the Prisoner" that is relevant in the Game Theory analysis (Filipe, 2007; Filipe, Coelho & Ferreira, 2005). This problem is posed in the Game Theory for situations in which the two players in the game have dominant strategies, what makes that the solution of the game is a dominant strategies' equilibrium. This equilibrium is stable and the players will not change their choices. What is a problem is that this kind of solution implies a total payoff that is under the result one that the players could have if they had some form of cooperation between them. In these situations, the players will choose the dominant strategy (which in the case of the natural resources is always the strategy of non conservation) and they will not have incentives to use efficiently and conserve the resource. The players are compelled to switch this strategy because they are functioning in competition conditions. So, this puts the players in a situation that represents a dilemma with ethical boundaries. By one side, the fisherman really thinks that is important to have a proper management policy for the use of the resource in the long term but by the other side he is compelled to have an egoistic and myopic view of the resource use and exploit it too much compared with the ideal inter-temporal production level.

The problem of over-fishing has long been claiming for good practices coming from international cooperation and coming from a preserving approach on the processes of decision making of resource management institutions. This may be some kind of a contribution to solve some of the multiple problems in the area of Commons. So, to solve the problem of maintaining the biodiversity, the preservation and related ethical issues in this area it is necessary to pose questions about how to use environment and Earth resources and how to treat other species, plant or animal. Cooperation has an important role in this subject.

3. The advantages of cooperation in a general model for fisheries

The purpose is to study the advantages of cooperation behavior. The presentation of this section allows to get a theoretical view for the bio-economic analysis of fishing agents.

In order to see how an optimal control problem may be important to analyze such a situation, as shortly as possible this problem in described this section.

First, assume asymmetric competitors with different fishing costs and that there is no cooperation.

The resource dynamics is given by the following differential equation (see, for example, Arnason (1990), Conrad and Clark (1987), Munro (1979)):

$$\frac{dx}{dt} = F(x) - h_1(t) - h_2(t), x(0) = x_0, t \in [0, \infty) \quad (1).$$

The variable x $(x \geq 0)$ is the state variable that denotes the biomass - fishery resource measured in terms of weight - $x(t) \in X \subset R_+$. X is the state space. $F(x(t))$ is the stock growth function. $F(x(t))$ is assumed to be a continuous function, concave in x, and so $F(0) = F(K) = 0$ for some $K > 0$ and for $F(x(t)) > 0$, $x(t) \in (0, K)$. The stock representing K is the carrying capacity of the resource.

Also:

$$h_i(t) = q_i E_i(t) x(t) \quad (2).$$

This equation represents the standard Schaefer harvest function. In the equation, q_i represents the "catch ability coefficient" of player i and E_i its fishing effort. This equation shows the relationship between fishing effort and catches of player i. If it is assumed that $q = 1$, so:

$$\pi(x, E_i) = (p_i x - c_i)E \quad (3).$$

Each player sells his own fished resource at a constant price p_i and supports the costs in direct proportion to his fishing effort and it is possible that $C(E_i(t)) = c_i E_i(t)$. C represents the global cost and c_i is the unit cost of fishing effort to the player i. So, player i will attempt to maximize the present value of the net economic revenue from the fishery over time:

$$PV_i(E_1, E_2) = \int_0^\infty e^{-\delta t} \pi_i(x, E_i) dt, i = 1,2$$

subject to

$$\frac{dx}{dt} = F(x(t)) - q_1 E_1(t) x(t) - q_2 E_2(t) x(t), \quad (4).$$
$$x(0) = x_0, t \in [0, \infty)$$

The variable E is defined according $0 \leq E_i(t) \leq E_i^{\max}$ and $\delta > 0$ is the player i discount rate. Both players may face different costs, prices and fishing technologies.

This optimal control (linear) problem, with *x(t)* as the state variable and E(t) as the control variable, allows to conclude that there exists an unique optimal solution and an optimal steady state biomass x^*. This solution is given by the equation:

$$\delta = F'(x^*) - \frac{c'(x^*)F(x^*)}{p - c(x^*)} \quad (5)$$

This equation works as a resource investment rule. It states, in effect, that an agent should invest in the resource up to the point that the yield on the marginal investment in the resource (RHS of the equation) is equal to the social rate of discount.

Besides, if the vessel capital employed in harvesting the resource is perfectly malleable, the optimal approach path to x^* is the most rapid one. In fact, in terms of the variable *h(t),* the following solution holds:

$h^*(t) = F(x^*)$, if $x = x^*$;

$h^*(t) = h^{\max}$, if $x > x^*$ (6)

and $h^*(t) = 0$, if $x < x^*$

If the capital employed is not perfectly malleable, or if the appropriate optimal control model is non-linear (e.g. because the demand for fish exhibits finite elasticity), the most rapid approach path is no longer optimal (see Miller and Munro, 2002).

Equation (5) gives the optimal solution when there is a problem for just one single state. If there are two players (states), both competing for the same fishing stock, the solution (Clark, 1980) will be determined by:

$$h_1^*(t) = \begin{cases} h_1^{\max} & if \quad x(t) > \min(x_1^*, x_2^\infty) \\ F(x) & if \quad x(t) = \min(x_1^*, x_2^\infty) \\ 0 & if \quad x(t) < \min(x_1^*, x_2^\infty) \end{cases} \quad (7),$$

$$h_2^*(t) = \begin{cases} h_2^{\max} & if \quad x(t) > x_2^\infty \\ 0 & if \quad x(t) \leq x_2^\infty \end{cases} \quad (8).$$

This means that when the players act independently, the Nash non-cooperative feed-back solution is such that the resource will be depleted in a most rapid approach manner until the bionomic level x_2^{∞} has been reached. That is, in the two players' game, the shared stock resource can be subject to overexploitation if an agreement cannot be achieved between the two players.

The cooperation appears as a way to overcome the consequences of negative externalities arising from the exploitation of the resource. In Filipe (2006), it is shown that in some situations cooperation is not necessary or indispensable. However, in general, the non-cooperative agents' behavior of leads to sub-optimal solutions and, from the society point of view, a better solution would be reached through a cooperative behavior.

4. Cournot-Nash model for fisheries

Besides the optimal control problem we have seen, we may have an interesting model based on the Cournot oligopoly model that allows us to conclude that cooperation brings very interesting results when we intend to preserve species and that cooperation improve rents for fishers. In fact, the Cournot-Nash model we implemented is a simple model and it has the big advantage of being easily understood by the stakeholders of fishing sector. This model shows the disadvantages of non-cooperation. An extension of the model shows, as well, that cooperation between agents allows better results by improving their situation and the levels of fish stocks.

Considering the Cournot model and integrating Nash equilibrium concept, usually used in theory of games and considering yet fishing effort, it is possible to study the issue of efficiency and overcapitalization in fisheries in a Nation's waters (see Filipe, 2006).

Captures of this species are the quantities (q) used in the traditional Cournot Model. In the usual fishing theories, this variable, *quantities,* has a formal relationship with fishing effort. In this model, this variable (*quantities)* is replaced by another variable, related to that one, precisely the *fishing effort (E)*.

So, the usual equations

$$\pi_i\,(q_1;\, q_2) = RT_i - CT_i,\ i=1,2 \qquad (9)$$

are replaced in the model by the equations

$$\pi_i\,(E_1;\, E_2) = RT_i - CT_i,\ i=1,2;\ q_i = f(E_i;X);\ (10)$$

E_i is the fishing effort used by FP_i *(FP* are the Fishing Producers) and X is the biomass level for the specie.

The Cournot model and the consequent Cournot-Nash equilibrium allow to analyze the contribution of cooperation for the preservation of stocks and to analyze its contribution for the stabilization of fishers' rents (Filipe, 2006).

With the maximization of aggregate fishing effort it is expected to reach a lower level than the sum of the reached levels for each individual solution. This is consistent with benefits expected for fishing producers, because fishing costs are expected to be lower. As an additional result, it is expected that the market price would be higher and the aggregate rent would be higher, as well. Besides, as the aggregate fishing effort is expected to be lower, it is expectable that fishers will control catches as well, and consequently, also to get a stock's management more compatible with conservative objectives. These conclusions are the expected results from the usual analysis of Cournot and cartel models (Filipe, 2006).

These conclusions permit to confirm evidences that cooperation is an important factor for the preservation of this specie and it is important to keep high fisher's rents levels. Besides the political reasons, fishers may promote some measures to reduce catches and to organize markets, preserving species for the future generations and protecting fishing present interests. Fishers may manage catches in order to control the activity of fleets and in order to control fishing effort. Consequently, levels for catches may decrease and species' stocks may be well managed. Stocks may be improved and fishers' rents may benefit with this kind of management. In addition, costs may decrease because producers may adjust their production capacity to the required supplies to match the demand of fishing product in the market.

These behaviors represent a genuine form of cooperation.

5. Concluding Remarks

The analysis for fisheries permits the opportunity of studying the role of regulation and cooperation on stocks recovery.

The main conclusions of the paper are the following:

First, cooperation contributes to regulate catches. It seems a good way to support high prices and high rents for fishers and to contribute to preserve stocks. The study confirms these evidences and shows that, even for higher catches, higher levels for stocks could be supported, as well.

This analysis shows that cooperation can be well understood by the stakeholders of the fishing sector and it proves that there are great benefits, through just a simple way of managing fisheries.

Second, the Cournot-Nash model used to analyze this situation has evident advantages. This model contributes for a better understanding of fishing problems. It seems that this study is very useful for authorities to plan and to rule fishing and for a good communication between national and local institutions of the fishing sector. This general model is easily understood by the stakeholders of the fishing sector.

It is a very simple model that can be well applied by the public decision-makers and it seems to be well adapted to fishing realities. The model is very flexible, adjustable and appropriate to analyze any species since one can adjust it to the available data for the specie object of study. It is very relevant for situations in which it is necessary urgent adjustments for consumption or production.

The flexibility of the model allows us to shape it according to the available information. However, it is necessary to have a minimum of information for variables such as stocks, fishing effort, catches or costs. Besides, this study does not include the analysis of any problems emerged from offers made by foreign fleets.

This model gives to the cooperation a central place in the context of management of a living resource, either in exploitation field or in the market for the resource studied.

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