International Fishery under Asymmetry and Imperfect Competition

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Abstract

Comparative statics is given of international competition in fishery with two asymmetric countries having different catchability coefficients, unit fishing effort costs, subsidies to and taxes on fishing, and numbers of firms. Two cases are analyzed,in one of which perfect competition prevails in the markets for the harvested fish and in the other they are oligopolistic

Introduction

In paper we will reexamine the problems analyzed by Ruseski (1998) by introducing asymmetries in his two country or fleet model of commercial fishing from the common property fishing ground. We also indicate how our analysis can be extended to deal with imperfect competition in the markets for harvested fish. We will find that our comparative static approach will make it possible to easily analyze more complex cases than Ruseski's under symmetry and perfect competition.

2. Asymmetries in Catchabilities, Subsidies and Management Costs

We assume two countries or fleets harvesting fish from the common property fishing ground. Let x be the fish stock and let q_i, E_i and $c_i \equiv c_{io} + s_i$ be the catchability coefficient, fishing effort, net unit cost of fishing effort (inclusive tax or exclusive subsidy), where c_{io} and s_i are unit fishing effort cost and tax (if $s_i > 0$) on or subsidy (if $s_i < 0$) to unit fishing efforts of country i, i = 1,2. Furthermore, let e_{1i} and e_{2j} be the fishing effort of the ith and jth firms of countries 1 and 2 respectively, where $i = 1,2,...,n_1$, $j = 1,2,...,n_2$. In the absence of fishing the fish stock grows according to

$$G(x) = rx\left(1 - \frac{x}{K}\right), \tag{1}$$

where r is the intrinsic rate of growth and K is the carrying capacity of the fishing ground. Country i's harvest H_i is assumed to be proportional to its fishing effort and the fish stock, hence

$$H_i = q_i E_i x \,, i = 1,2 \,. \tag{2}$$

Following Ruseski (1998), we assume the steady state to be prevailing:

$$\frac{dx}{dt} = G(x) - (H_1 + H_2) = 0 \,. \tag{3}$$

This yields

$$x = \frac{K}{r}\left(r - q_1 E_1 - q_2 E_2\right). \tag{4}$$

Firm i and firm j in country 1 and country 2 earn profits π_{1i} and π_{2j}, respectively, given by

$$\pi_{1i} = pq_1 e_{1i} x - c_1 e_{1i} \tag{5.1}$$

$$\pi_{2j} = pq_2 e_{2j} x - c_2 e_{2j} \,, \tag{5.2}$$

where $i = 1,2,...,n_1$, $j = 1,2,...,n_2$

Let $b \equiv \frac{pK}{r}$,and define the new individual and aggregate variables by

$$x_{1i} \equiv q_1 e_{1i} \,,\; X_1 \equiv \sum x_{1i}$$

$$x_{2j} \equiv q_2 e_{2j} \,,\; X_2 \equiv \sum x_{2j}$$

If all firms maximize their profits under the Cournot behavioristic assumption about all of their rivals' fishing efforts (hence, harvest rates), the following first order conditions hold.

$$\frac{\partial \pi_{1i}}{\partial e_{1i}} = q_1 b(r - X_1 - X_2) - q_1 b x_{1i} - c_1 = 0 \,, \tag{6.1}$$

$$\frac{\partial \pi_{2j}}{\partial e_{1j}} = q_2 b(r - X_1 - X_2) - q_2 b x_{2j} - c_2 = 0 \tag{6.2}$$

We assume q_1 and q_2 remain constant. However, since two countries' fishery management policies may not be the same, c_1 and c_2 may differ. Solving x_{1i} as a function of X_1, X_2 and c_1, we get

$$x_{1i} \equiv \varphi_1(X_1, X_2, c_1) \,, \tag{7.1}$$

$$\varphi_{11} = \varphi_{12} = -1, \varphi_{1c_1} = -\frac{1}{q_1 b} \tag{7.1'}$$

Similarly solving (6.2) with respect to x_{2j},

$$x_{2j} \equiv \varphi_2(X_1, X_2, c_2) \quad (7.2)$$

where

$$\varphi_{21} = \varphi_{22} = -1, \varphi_{2c_2} = -\frac{1}{q_2 b} \quad (7.2')$$

By definition

$$X_k = n_k \varphi_k(X_1, X_2, c_k) \equiv \varphi_k^*(X_1, X_2, n_k, c_k), \quad k=1,2. \quad (8)$$

where in the light of (7.1′) and (7.2'),

$$\frac{\partial \varphi_k^*}{\partial X_1} = -n_k, \frac{\partial \varphi_2^*}{\partial X_2} = -n_k, \frac{\partial \varphi_2^*}{\partial c_k} = -\frac{n_k}{q_k b}, \frac{\partial \varphi_k^*}{\partial n_k} = \varphi_k$$

$$k=1,2 \quad (8')$$

Utilizing the qualitative information contained in (8') we are able to diagrammatically determine the equilibrium values of X_1 and X_2 as functions of the parameters c_1, c_2, n_1 and n_2 as follows.

Consider first (8) for k=1. Given X_2, c_1 and n_1, the line for φ_1^* is downward sloping. Hence, it has the unique intersection E_1 with the 45 degree line emanating from the origin. If X_2 increases, the new intersection becomes E_2, leading to a lower value for X_1. The effects of changes in c_1 and n_1 can be similarly analyzed. Hence, if c_1 increases, X_1 decreases, and if n_1 increases, X_1 increases. Therefore,

$$X_1 \equiv \psi_1(X_2, n_1, c_1), \quad (9.1)$$

where

$$\frac{\partial \psi_1}{\partial X_2} < 0, \frac{\partial \psi_1}{\partial n_1} > 0, \frac{\partial \psi_1}{\partial c_1} < 0 \quad (9.1')$$

A similar argument applied to (8.2) yields

$$X_2 \equiv \psi_2(X_1, n_2, c_2), \quad (9.2)$$

where

$$\frac{\partial \psi_2}{\partial X_1} < 0, \frac{\partial \psi_2}{\partial n_2} > 0,, \frac{\partial \psi_2}{\partial c_2} < 0. \quad (9.2')$$

Given c_1, c_2, n_1 and n_2, the equilibrium values of X_1 and X_2, which satisfy (9.1) and (9.2) simultaneously, are given by the intersection E_1 of two downward sloping . The slopes for ψ_1 and ψ_2 are $-\frac{1+n_1}{n_1}$ and $-\frac{n_2}{1+n_2}$,respectively. *Ceteris paribus*, if n_1 increases, the line for $\psi_1(X_2, n_1, c_1)$, which has a steeper slope than before, moves upward in the light of the second inequality in (9.1′). Consequently, the new intersection becomes E_2, resulting in a larger equilibrium value of X_1 and a smaller one of X_2. *Ceteris paribus*, if c_1 increases, the line for $\psi_1(X_2, n_1, c_1)$, which has the same slope as before, shifts downward in the light of the third inequality in (9.1′), therefore, the new equilibrium values of X_1 and X_2 become smaller and larger, respectively. The effects of changes in n_2 and c_2 can be similarly analyzed. Hence the equilibrium values of X_1 and X_2 are expressed as functions of n_1, n_2, c_1 and c_2.

$$X_k = G_k(n_1, n_2, c_1, c_2), k=1,2 \quad (10)$$

Totally differentiating (10) and taking into account (8'), we evaluate the partial derivatives of G_1 and G_2 as follows. As the effects of changes in n_2 and c_2 are obtainable if the suffixes in the expressions denoting those in n_1 and c_1 are interchanged, we show only the expressions relating to changes in n_1 and c_1 in the following analysis.

$$\begin{cases} \frac{\partial G_1}{\partial n_1} = \frac{(1+n_2)\varphi_1}{1+n_1+n_2} > 0 \\ \frac{\partial G_2}{\partial n_1} = -\frac{n_2\varphi_1}{1+n_1+n_2} < 0 \end{cases} \quad (11.1)$$

$$\begin{cases} \frac{\partial G_1}{\partial c_1} = -\frac{n_1(1+n_2)}{q_2 b(1+n_1+n_2)} < 0 \\ \frac{\partial G_2}{\partial c_1} = -\frac{n_1 n_2}{q_1 b(1+n_1+n_2)} < 0 \end{cases} \quad (11.2)$$

According to (11.1), if the number of fishing firms (licencees) in country 1 increases, its total harvest increases but that of country 2 decreases. Expressions in (11.2) show that if country 1's subsidy to fishing effort increases,itss total harvest increases but that of country 2 decreases. Note that the increase in subsidy is equivalent to the decrease in net fishing effort cost.

We use (11) and (12) to further derive the following results:

$$\begin{cases} \frac{\partial}{\partial n_1}(X_1 + X_2) = \frac{\varphi_1}{1+n_1+n_2} > 0 \\ \frac{\partial}{\partial n_1}(E_1 + E_2) = \frac{\{(1+n_2)q_2 - n_2 q_1\}\varphi_1}{q_1 q_2(1+n_1+n_2)} \begin{matrix} \geq \\ < \end{matrix} 0 \\ \Leftrightarrow \frac{q_1}{q_2} \begin{matrix} \leq \\ > \end{matrix} 1 + \frac{1}{n_2} \end{cases} \quad (11.3)$$

$$\frac{\partial x_{1i}}{\partial n_i} < 0, \frac{\partial x_{2j}}{\partial n_1} < 0. \qquad (11.4)$$

According to (11.3), if the number of firms increases in country 1, the total harvest by two countries increases but whether the total fishing efforts by two countries will increase, decrease or remain unchanged depends on the ratio of country 1's catchability coefficient to country 2's and the number of firms in country 2. In Ruseski's case, $q_1 = q_2$, therefore the total fishing efforts of the two countries increase. According to (11.4), an increase in country 1's number of firms leads to decreases both country 1's and country 2's individual firms' harvest rates.

$$\begin{cases} \frac{\partial}{\partial c_1}(X_1 + X_2) = \frac{n_1}{q_1 b(1+n_1+n_2)} < 0 \\ \frac{\partial}{\partial c_1}(E_1 + E_2) = \frac{n_1\{-(1+n_2)q_2 + n_2 q_1\}}{q_1^2 q_2 b(1+n_1+n_2)} \gtrless 0 \\ \Leftrightarrow \frac{q_1}{q_2} \gtrless 1 + \frac{1}{n_2} \end{cases} \qquad (11.5)$$

$$\frac{\partial x_{1i}}{\partial c_i} < 0, \frac{\partial x_{2j}}{\partial c_1} > 0. \qquad (11.6)$$

An increase in country 1's subsidy unambiguously increases the total harvest by two countries but how the total fishing efforts by two countries change depends on the relationship between q_1/q_2 and n_2. Under the same condition, individual firms' harvest rates in country 1 and country 2 decrease and increase, respectively.

We now turn to rent shifting effects of changes in the number of licencees. Let π_k be the total profits of country k. Then

$$\pi_k = bX_k(r - X_1 - X_2) - \frac{c_k}{q_k}X_k,\ k=1,2 \qquad (12.1)$$

Taking into account the first order condition (6.1) as well as (11.1) and $x_{1i} = \frac{X_1}{n}$, we evaluate $\frac{\partial \pi_1}{\partial n_1}$ as follows:

$$\frac{\partial \pi_1}{\partial n_1} = \frac{bX_1\varphi_1(1-n_1+n_2)}{n_1(1+n_1+n_2)} \qquad (13.1)$$

$$\gtrless 0 \Leftrightarrow n_1 \lesseqgtr 1+n_2$$

For the total profits of country 2,

$$\pi_2 = \sum \pi_{2j} = bX_2(r - X_1 - X_2) - \frac{c_2}{q_2}X_2 \qquad (12)$$

The evaluation of the partial derivative is

$$\frac{\partial \pi_2}{\partial n_1} = -\frac{2bX_2\varphi_1}{1+n_1+n_2} < 0 \qquad (13.2)$$

The total profits of country 1 may increase, decrease or remain unchanged but those of country 2 unambiguously decrease if country 1's number of firms increases. Since the total welfare of country i is defined by

$$W_i \equiv \pi_i - n_i F_i\ ,\ i = 1,2$$

where F_i is country i's fishery management cost per firm, (13.1) and (13.2) lead to

$$\frac{\partial}{\partial n_1}(W_1 + W_2) = \frac{b\varphi_1\{\varphi_1(1-n_1+n_2) - 2n_2\varphi_2\}}{1+n_1+n_2} - F_1 \qquad (15)$$

The sign of (15) is generally indeterminate. However,in the symmetric case of identical catchabilitycoefficients and number s of firms

$$\frac{\partial}{\partial n_1}(W_1 + W_2) < 0 \text{ if } n_1 = n_2 \geq 1,$$

which confirms the result of Ruseski.

The optimal numbers of firms in two countries are determined as follows. Maximizing W_1 with respect to n_1, we derive the implicit reaction function of country 1

$$\varphi_1^2 = \frac{F_1(1+n_1+n_2)}{b(1-n_1+n_2)} \equiv \tau_1 \qquad (15.1)$$

where, given c_1 and c_2, φ_1 is a function of X_1 and X_2, hence of n_1 and n_2. Similarly, the implicit reaction function of country 2 is

$$\varphi_2^2 = \frac{F_2(1+n_1+n_2)}{b(1-n_2+n_1)} \equiv \tau_2 \qquad (15.2)$$

where, given c_1 and c_2, φ_2 is also a function of n_1 and n_2. From (11.4), φ_1 and φ_2 are both decreasing in n_1 and n_2. Hence (15.1) is solvable with respect to n_1 as a function of n_2, and (15.2) with respect to n_2 as a function of n_1.Let the solutions of (15.1) and (15.2) be

$$n_1 = R_1(n_2)\ , \qquad (16.1)$$

$$n_2 = R_2(n_1), \qquad (16.2)$$

which are the reaction functions of country 1 and country 2, respectively. However, R_1 and R_2 are not necessarily monotonous decreasing in n_2 and n_1, respectively. If monotonicity and appropriate curvatures for (16.1) and (16.2)are assumed, there exists a unique equilibrium pair of n_1 and n_2.

Next, we examine the effects on π_1, π_2 and $\pi_1 + \pi_2$ of a change in c_1.

$$\frac{\partial \pi_1}{\partial c_1} = -\frac{2(1+n_2)X_1}{q_1(1+n_1+n_2)} < 0 \qquad (17.1)$$

$$\frac{\partial \pi_2}{\partial c_1} = \frac{2n_1 X_2}{q_2(1+n_1+n_2)} > 0 \qquad (17.2)$$

$$\frac{\partial}{\partial c_1}(\pi_1+\pi_2) \overset{\geq}{\underset{<}{}} 0 \Leftrightarrow \frac{q_1}{q_2} \overset{\geq}{\underset{<}{}} \frac{(1+n_2)X_1}{n_1 X_2}. \quad (17.3)$$

Country 1's and country 2's total profits and decrease, respectively, if country 1 increases its subsidy but the total profits by two countries may increase,decrease or remain unchanged under the same condition.If two countries are symmetric, the second inequality in (17.3) holds,hence the total profits by the two countries increase.

3 .Imperfect Competition

In Section 2, we have assumed perfect competition in the fish markets in two countries. In this section we will assume that the fish markets in both countries are under oligopoly and two markets are completely segmented. Under market segmentation, the prices of the fish in two countries may differ. Let therefore

$$p_k = f_k(X_k x), f_k' < 0, i = 1,2 \qquad (18)$$

be country 1 and country 2's inverse demand functions, where p_1 and p_2 are the prices of the harvested fish in country 1 and country 2, respectively,and $\beta \equiv \frac{k}{r}$, $v_1 \equiv \frac{c_1}{q_1}, v_2 \equiv \frac{c_2}{q_2}$.

Then,

$$\pi_{1i} = \beta x_{1i} f_1(X_1 x)(r - X_1 - X_2) - v_1 x_{1i}, \qquad (19.1)$$

$$\pi_{2j} = \beta x_{2j} f_2(X_2 x)(r - X_1 - X_2) - v_2 x_{2j} \qquad (19.2)$$

Under the Cournot behavioristic assumption, the first order condition for maximization of π_{1i} with respect to e_{1i} (i.e. x_{1i})and that of π_{2j} with respect to e_{2j} (i.e. x_{2j}) yield

$$\frac{\partial \pi_{1i}}{\partial x_{1i}} = \beta(r - X_1 - X_2)f_1 - \beta x_{1i} f_1 + \beta^2 x_{1i}(r - X_1 - X_2)(r - 2X_1 - X_2)f_1' - v_1 = 0 \qquad (20.1)$$

$$\frac{\partial \pi_{2j}}{\partial x_{2j}} = \beta(r - X_1 - X_2)f_2 - \beta x_{2j} f_2 + \beta^2 x_{2j}(r - X_1 - X_2)(r - X_1 - 2X_2)f_2' - v_2 = 0 \qquad (20.2)$$

We assume that the following second order condition to hold.

$$\frac{\partial^2 \pi_{1i}}{\partial x_{1i}^2} < 0, \qquad (A21.1)$$

$$\frac{\partial^2 \pi_{2j}}{\partial x_{2j}^2} < 0, \qquad (A.21.2)$$

Furthermore ,we assume that

$$\frac{\partial^2 \pi_{1i}}{\partial x_{1i}\partial x_{1k}} < 0, \forall k \neq i, \frac{\partial^2 \pi_{1i}}{\partial x_{1i}\partial x_{2j}} < 0, \forall i, j \qquad (A.22.1)$$

$$\frac{\partial^2 \pi_{2j}}{\partial x_{2j}\partial x_{2h}} < 0, \forall h \neq j, \frac{\partial^2 \pi_{2j}}{\partial x_{2j}\partial x_{1i}} < 0, \forall i, j \qquad (A.22.2)$$

These assumptions imply that for any two firms, their fishing efforts in efficiency unit are strategic substitutes each other. We note that $\frac{\partial^2 \pi_{1i}}{\partial x_{1i}\partial v_1}$<0 and $\frac{\partial^2 \pi_{2j}}{\partial x_{2j}\partial v_2} < 0$, and that (A22.1) and (A.22.2) are replaced by

$$\frac{\partial^2 \pi_{1i}}{\partial x_{1i}\partial X_1} < 0, , \frac{\partial^2 \pi_{1i}}{\partial x_{1i}\partial X_2} < 0, \qquad (A.22.1')$$

$$\frac{\partial^2 \pi_{2j}}{\partial x_{2j}\partial X_2} < 0, \frac{\partial^2 \pi_{2j}}{\partial x_{2j}\partial X_2} < 0. \qquad (A.22.2')$$

Solving (20.1) with respect to x_{1i} ,we get

$$x_{1i} = \varphi_1(X_1, X_2, v_1), \qquad (23.1)$$

where

$$\varphi_{11} \equiv \frac{\partial \varphi_1}{\partial X_1} < 0, \varphi_{12} \equiv \frac{\partial \varphi_1}{\partial X_2} < 0, \varphi_{13} \equiv \frac{\partial \varphi_1}{\partial v_1} < 0. \qquad (23.1')$$

Similarly from (20.2),

$$x_{1j} = \varphi_2(X_1, X_2, v_2) \qquad (23.2.)$$

with

$$\varphi_{21} \equiv \frac{\partial \varphi_2}{\partial X_1} < 0, \varphi_{22} \equiv \frac{\partial \varphi_2}{\partial X_2} < 0, \varphi_{23} \equiv \frac{\partial \varphi_2}{\partial v_2} < 0. \qquad (23.2')$$

Note that (23.1) and (23.2) are not reaction functions in the traditional sense of the word.They are introduced in order to simplify analysis of the existence of the Cournot equilibrium in our model.By definition of X_k

$$, X_k = n_k \varphi_k(X_1, X_2, v_k), k = 1,2. \qquad (24)$$

Hence (24) is solvable as

$$X_k = G_k(n_1, n_2, v_1, v_2), k = 1,2. \qquad (25)$$

Assume that the matrix D defined below be positive.

$$D \equiv \begin{vmatrix} 1-n_1\varphi_{11} & -n_1\varphi_{12} \\ -n_2\varphi_{21} & 1-n_2\varphi_{22} \end{vmatrix} > 0 \qquad \text{(A.26)}$$

Then the partial derivatives of G_1 and G_2 with respect to changes in n_1 and v_1 have the following signs. In the following analysis we will be concerned only with the effects of changes in country 1's parameters.

$$\frac{\partial G_1}{\partial n_1} = \frac{\varphi_1(1-n_2\varphi_{22})}{D} > 0$$
$$\frac{\partial G_1}{\partial v_1} = \frac{n_1\varphi_{13}(1-n_2\varphi_{22})}{D} < 0$$
$$\frac{\partial G_2}{\partial n_1} = \frac{n_2\varphi_1\varphi_{21}}{D} < 0 \qquad (27)$$
$$\frac{\partial G_2}{\partial v_1} = \frac{n_1 n_2\varphi_{21}\varphi_{13}}{D} > 0.$$

Using (27), we can show that

$$\frac{\partial}{\partial n_1}(X_1 + X_2) = \frac{\varphi_1(1-n_2\varphi_{22}+n_2\varphi_{21})}{D} \gtrless 0. \qquad (28.1.)$$

$$\frac{\partial}{\partial n_1}(E_1 + E_2) = \frac{\varphi_1}{Dq_1q_2}\left\{ q_2(1-n_2\varphi_{22}) + q_1 n_2\varphi_{21} \right\} \gtrless 0 \qquad (28.2)$$

$$\operatorname{sgn}\frac{\partial}{\partial v_1}(X_1 + X_2) = -\operatorname{sgn}\frac{\partial}{\partial n_1}(X_1 + X_2) \qquad (28.3)$$

$$\operatorname{sgn}\frac{\partial}{\partial v_1}(E_1 + E_2) = -\operatorname{sgn}\frac{\partial}{\partial n_1}(E_1 + E_2). \qquad (28.4)$$

Since the steady state fish stock x is given by

$$x = \beta(r - X_1 - X_2),$$

(28.1) implies that the effects on the steady state fish stock of an increase in the fleet size of country 1 are indeterminate.According to (28.3), if the steady state fish stock increases(decreases) with an increase in the fleet size ,it decreases(increases) with an increase in the unit fishing effort cost or with a decrease in the efficiency of the fishing effort.

We will now analyze how the changes in n_1 and v_1 will affects the total profits of the two countries. By definition,

$$\Pi_k = \beta X_k f_k(\beta X_k(r - X_1 - X_2)) - v_k X_k, \quad k=1,2 \qquad (29)$$

Partially differentiating Π_1 with respect to n_1 ,taking into account the first order condition for profit maximization (20.1) as well as well as the first and the third inequalities in (27), and rearranging we have

$$\frac{\partial \Pi_1}{\partial n_1} = (n_1 - 1)\{v_1 - \beta(r - X_1 - X_2)f_1\}\frac{\partial X_1}{\partial n_1} - \beta X_1\{f_1 + \beta X_1(r - X_1 - X_2)f_1'\}\frac{\partial X_2}{\partial n_1}, \qquad (30.1)$$

Since we may reasonably assume nonnegative total profits as well as nonnegative marginal revenue for the total harvested fish for country 1

$$MR_1 \equiv f_1 + \beta X_1(r - X_1 - X_2)f' \geq 0,$$

the expression in the first braces is seen to be nonpositive and the second one is nonnegative. Hence the sign of the expression in the brackets is indeterminate in general. However, under perfect competition, $\varphi_{21} = \varphi_{22} = -1$. On the other hand ,the first order condition for profit maximization yields

$$v_1 - \beta(r - X_1 - X_2)f_1 = -\beta p\varphi_1.$$

The expression in the brackets is therefore equals to $\beta p\varphi_1(n_2 + 1 - n_1)$. Hence ,if perfect competition prevails,

$$\frac{\partial \Pi_1}{\partial n_1} \gtrless 0 \text{ according as } n_1 \lesseqgtr n_2 + 1.$$

This result coincides with (13.1) in Section 2.The partial derivative of Π_2 with respect to change in n_1

$$\frac{\partial \Pi_2}{\partial n_1} = -\beta X_2\{f_2 + \beta X_2(r - X_1 - X_2)f_2'\}\frac{\partial X_1}{\partial n_1} + (n_2 - 1)\{v_2 - \beta(r - X_1 - X_2)f_2\}\frac{\partial X_2}{\partial n_1} \qquad (30.2)$$

If $\Pi_2 \geq 0$ and $MR_2 \geq 0$, the sign of the right hand side of (30.2) is generally indeterminate in the light of the first and third expressions in (27). On the other hand, perfect competition leads to

$$\frac{\partial \Pi_2}{\partial n_1} = -\frac{2\beta p\varphi_1\varphi_2 n_2}{D} < 0.$$

This coincides with (13.2) in Section 2. We can prove in view of (27) that $\frac{\partial \Pi_1}{\partial v_1} < 0$ if $\Pi_1 \geq 0$ and $MR_1 \geq 0$ .On the other hand, the sign of $\frac{\partial \Pi_2}{\partial v_1}$ is indeterminate even if $\Pi_2 \geq 0$ and $MR_2 \geq 0$

4 . Concluding Remarks

In this paper we have conducted a systematic, comparative static analysis of international commercial fishing from the common fishing ground by introducing asymmetries regarding catchability coefficients, unit fishing effort costs and national fishery management costs. We have found that the difference in the catchability coefficients between two fishing countries is relevant to comparative static results. In the latter part of our analysis, we have extended Ruseski's analysis by assuming oligopoly in the markets for the harvested fish. This extension was made possible by applying our systematic comparative static method which did not require us to explicitly compute the equilibrium values of relevant variables as was necessary in Ruseski (1998).

REFERENCES

Gordon, H.S. (1954), "The Economic Theory of a Common Property Resource: The Fishery", *Journal of Political Economy* 2, 124-142.

Mesterton-Gibbons, M. (1993), "Game Theoretic Resource Modelling", *Natural Resource Modelling* 7, 93-147.

Okuguchi, K. (1976), *Expectations and Stability in Oligopoly Models*, Springer-Verlag (Berlin, Heidelberg and N.Y.).

Okuguchi, K. and F. Szidarovszky (1990), *The Theory of Oligopoly with Multi-product Firms*, Springer-Verlag (Berlin, Heidelberg and N.Y.). Second and revised edition ,1999

Okuguchi, K. (1998), "Long-Run Fish Stock and Imperfectly Competitive Commercial Fishing", *Keio Economic Studies* 35, 9-17.

Ruseski, G. (1998), "International Fish Wars: The Strategic Roles for Fleet Licencing and Effort Subsidies", *Journal of Environmental Economics and Management* 36, 70-88.

Schaefer, M.B. (1957), "Some Considerations of Population Dynamics and Economics in Relation to the Management of Marine Fisheries", *Journal of the Fisheries Research Board of Canada* 14, 635-647.

Szidarovszky, F, and K. Okuguchi (1998), "An Oligopoly Model of Commercial Fishing", *Seoul Journal of Economics* 11,321-330.