Co-management and Labor Stickiness in Fishing Communities: Determination of the Optimal Number of Vessels

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Abstract: In the recent years, resource depletion of inshore and coastal fisheries has seriously impacted Taiwan. Local fishing communities' economic profits in these fisheries have declined and resulted in lower earned incomes for the fishermen. These phenomena have lead many scholars, government agencies and fishing communities to evaluate the optimal number of operating vessels in these fisheries. This study has explicitly applied the concepts of community-based co-management, fish market concentration and labor stickiness to an economic model that can be used to determine the optimum number of fishing vessels in a fishing community. One corollary of this approach is that we modify the traditional assumption regarding labor mobility in a fishing community and explore here how labor stickiness to the extent that it exists in Taiwan's fishing communities might bias traditional fishing management policies and influence the determination of optimal number of vessels. In addition, the Herfindahl index (H), which measures the degree of concentration in the structure of a fishery market, will also affect the final determination of the optimal number of vessels. Results suggest that when there are no labor mobility barriers, then with flexible fishing operation costs, the optimal number of vessels and the fish stock would be smaller. Larger values of H (i.e., Herfindahl index) and greater differentials in the fishing efficiency index in the fishing community also result in relatively fewer vessels and fish stock. Finally, as to the impacts of changing fish stock growth rate and fish price on the optimal vessel number and fish stock are also discussed.

Keywords: community-based co-management, labor stickiness, market concentration

(1) Introduction

Currently in Taiwan, crew employment problems and low operating profits in the fishery industry give vessel owners no incentive to renew their fishing equipment, and have led owner of older vessels to undertake illegal smuggling activities. The Agricultural Committee Council (ACC) is therefore focusing on how to manage and improve fishing operating conditions in the fishing community. In fact, the ACC either implemented a program aimed at speeding up the retirement of old vessels. Between 1991 to 1995, at a cost of 3 billion NT dollars, this vessel-reduction policy led to the purchase of 2337 vessels (118,354.29 tons) that were more than 12 years old. This study appraises the priorities and conditions of this old-vessel buyback procedure and provides some suggestions for the future based on aspects of fishery economic theory.

The buyback conditions and priorities of the ACC's scheme were based on the age of vessel.

For example, in the first year (i.e. 1991) the vessel more than 20 years old were the first priority. This was based on the assumption that older boats had a lower fishing efficiency or vessel productivity (Chuang, 1999). It also assumes that the optimal number of vessels to be purchased or conversely the optimal number of vessels in the fleet, can be determined by the basis of fishing efficiency (Matthiasson, 1997). Since a vessel's fishing efficiency is resulted in the harvest, and in particular in a vessel's harvest market share with respect to the fishing community, the market share can therefore also be used to derive the optimal number of vessels. From this point of view, inequalities in fishing efficiency and the degree of market concentration in a given fishing community are factors that need to be considered in the formulation of fishery resource management policy. This is the approach developed in the present paper. One corollary of this approach is that the Herfindahl index, which measures the degree of concentration in the structure of a fishery market, will also affect the determination of the optimal number of vessels.

A second aspect of the ACC's buyback program was that the government apparently dominated the purchasing procedure. However, recent fishing management papers, such as Sen & Nielsen (1996), Dubbink & Wliet (1996), Pomeroy & Carlos (1997) and Pomeroy & Berkes (1997), have agreed that where over-fishing and overcapacity have led to fish resource depletion problems, the resolutions can be achieved through co-management by government and fishing communities. The co-management approach is therefore incorporated into the model developed in this paper. In addition, we modify the traditional assumption regarding labor mobility in a fishing community (i.e. labor can move in and out a fishing community freely). Terkla, Doeringer and Moss (1988) have provided empirical evidence of stickiness in the labor market of fishing communities, and we explore here how labor stickiness to the extent that it exists in Taiwan's fishing communities might bias traditional fishing management policies and influence the determination of optimal number of vessels.

In the next section, we determine the optimal number of vessels in an open-access fishery, and incorporate the ideas of market concentration and labor stickiness in the model. Co-management is considered in section III. Section VI contains a simulation analysis and discussion, and implications are summarized in the final section.

2. Theoretical Model of an Open-access Fishery

Consider the determination of the optimal number of vessels for a fishing community with access to special fishing area (or fishing ground) that is used to improve both the fishing efficiency of its vessels and the income of its fishermen. According to this optimal vessel number, fisherman organizations in the fishing community can then establish a fishing management program that develops the community economy within the government's fishery management policies.

To determine the optimal number of vessels in the fishing community, we assume that the historical harvest fishing efficiency index (or fishing productivity index) is available for each vessel in the community. This index is based on the percentage of a vessel's harvest with respect to the total harvest for the whole community. Supposing that there are N (N = 1,...,n) vessels in the community, then the vessels can be ordered by their efficiency index number into an N-element, arrays such that the harvest efficiency of vessel n is higher than that of vessel n + 1.
Next, convert the harvest fishing efficiency index of each vessel to its catchability coefficient, that is

$$q_i = f(\mu_i)\,,\ f'(\mu_i) > 0\,,\ f''(\mu_i) \le 0\,,\ i = 1,\ldots,n \quad (1)$$

Here, μ_i represents the fishing harvest efficiency index of vessel i, and $\mu_1 \ge \mu_2 \ge \ldots \ge \mu_n$, q_i represents the catch-ability coefficient of vessel i. According to Cunningham, Dunn, and Whitmarsh (1985, p.30), q_i is also a proxy for the technological efficiency of vessel i and as such is a useful index in fishery management. The inequalities in catchability implied by the different fishing harvest efficiency indices in equation (1) would influence the vessels' fish catch, i.e.

$$h_i = q_i E_i b\,,\ i = 1,\ldots,n \quad (2)$$

where $h_i > 0$ is the harvest of vessel i, $E_i > 0$ is its fishing effort, and $b > 0$ is the fish stock in the specific fishing ground.
Traditional fishery economics studies, such as Anderson (1986), Clark (1990), Cunningham, Dunn, and Whitmarsh (1985), and Neher (1990) all assumed that labor (and capital) in the fishing community is moveable. The labor stickiness found by Terkla, Doeringer, and Moss (1988), however, means that there are in fact barriers (like the difficulty of job changing) to moving into and out of the labor force market in the fishing community. Clark (1990) also acknowledged that the labor stickiness effect would influence fishery equilibrium and fishing management policies although this was not incorporated into his model. In this study, labor stickiness is made an explicit part of the fishing operation costs, and we follow Von Weisacker (1980) and Mills (1984) in setting up the fishing cost function as below¡G

$$C_i = \alpha_i + \frac{E_i^2}{2\gamma}\ \ i = 1,\ldots,n \quad (3)$$

Here, $\alpha_i > 0$ is the fixed cost of vessel i, $\gamma > 0$ reflects the internal inefficiencies in an organization that result from labor (or capital) stickiness and the overuse of the labor force. According to Mills, γ is a measure of the flexibility of fishing operation costs.
Combining equations (1), (2) and (3), the fishing operation cost function of vessel i can be expressed as

$$C_i = \alpha_i + \frac{h_i^2}{2\gamma f^2(\mu_i) b^2}\ \ i = 1,\ldots,n \quad (4)$$

Thus, the operating profit of vessel i is

$$\pi_i = p h_i - \alpha_i - \frac{h_i^2}{2\gamma f^2(\mu_i) b^2}\ \ i = 1,\ldots,n \quad (5)$$

where p>0 is the fish price, and the first and second order conditions to maximize the profit are

$$\frac{d\pi_i}{dh_i} = p - \frac{h_i}{\gamma f^2(\mu_i) b^2} = 0\,,\ i = 1,\ldots,n\,; \quad (6)$$

$$\frac{d^2\pi_i}{dh_i^2} = \frac{-1}{\gamma f^2(\mu_i) b^2} < 0\,,\ i = 1,\ldots,n\,. \quad (7)$$

Following Conrad and Clark (1987), who referred to the Schaefer model, the relationship between steady state harvest and fish stock is

$$\sum_{i=1}^{n} h_i = \delta b (1 - \frac{b}{k})\,, \quad (8)$$

where $\delta > 0$ is the growth rate of the fishing resource stock, and $k > 0$ is the environmental carrying capacity. Combining equations (6) and (8) yields the stable fishing resource stock in a free and open-access situation:

$$b_{OA} = b_M \frac{2\delta}{p\gamma k\sum_{i=1}^{n} f^2(\mu_i) + \delta}, \qquad (9)$$

where $b_M = \frac{k}{2}$ is the fish stock under maximum sustainable yield (MSY). The previously unspecified function in equation (1) and now be written in a way that results the influence that the different catch-abilities on a stable fishing stock. There are many ways to express these inequalities (Waterson, 1984). For convenience, we assume that

$$f(\mu_i) = \mu_i,\ i = 1,....n.$$

From the above assumption, it follows $\sum_{i=1}^{n} f^2_{(\mu_i)} = \sum_{i=1}^{n} \mu_i^2 = H$. Where H is the Herfindahl index, and larger values indicate a greater differentiation among the catch-abilities in the fishing community. Adelman (1969) demonstrated that the Herfindahl index could be expressed as $H = \frac{v^2+1}{n}$, where v is the coefficient of variation of the fish harvest ratio. The Herfindahl index will therefore increase with increasing v or with a decreasing number of vessels in the community. Equation (9) can now be rewritten as

$$b_{OA} = b_M \frac{2\delta}{p\gamma kH + \delta}. \qquad (9a')$$

From equation (9a'), the following propositions can be established:

Proposition 1. let $k^* = \frac{\delta}{p\gamma H}$, then

(1) if $k^* > (<)k$, then $b_{OA} > (<)b_M$.

(2) $\lim_{\gamma \to 0} b_{OA} = k > b_M$, $\lim_{\gamma \to \infty} b_{OA} = 0$.

Proposition 1-(1) states that if the environmental carrying capacity is lower (higher) than the specified value (or according to Neher in 1990, the Maximum sustainable population), then the optimal fishing stock under open-access will be more (less) than that under MSY. Thus if the maximum fish stock that the current sustainable environment can support is lower than the specified value, then from the point of view of profit maximization, increasing the fish stock is beneficial. Conversely, if the maximum sustainable fish stock is higher, then a reduction in the fish stock would be more beneficial. Harvests above the MSY, i.e. $b_{OA} > b_M$ as a consequence of k*>k, would occur more frequently with decreasing r (degree of stickiness in the labor market), v (variance in the fishing harvest ratio), P (the fish price), and with increasing δ (fishing stock growth rate) and n (number of vessel in the community). Likewise, smaller catch-ability differentials in a fishing community will also result in more harvests that are above MSY.

Proposition 1-(2) states that if the labor market in a fishing community is quite sticky, then $b_{OA} = k$. This implies that the optimal fish stock is equivalent to the maximum sustainable yield under open-access conditions. In other words, in this situation, the total harvest level in the fishing community is equal to zero. It also implies that when the opportunity cost of a fishing operation is too high, the vessel owner has no incentive to fish. However, if the fishing operation cost is low and adaptable, as when b_{OA} = 0, there would on the contrary be no incentive for vessel owners to leave any of the fish resource stock unharvested.

Depending on the harvest efficiency index ranking, only more efficient vessel owners will get economic rents. The profits derived by the owner of a vessel with a specified efficiency index will be:

$$\pi_N = ph_N - \alpha_N - \frac{h_N^2}{2\gamma\mu_N^2 b^2} = 0. \qquad (10)$$

Combing equations (1), (6), and (9) yields

$$\mu_N = \left(\frac{2\alpha_N}{\gamma}\right)^{1/2} \left(\frac{H\gamma}{\delta} + \frac{1}{pk}\right). \qquad (11)$$

According to equation (11), for vessels operating in a special open-access fishery area belong to fishing community, the last one willing to fish has the fishing efficiency index £g$_{N.}$ That is, the optimal number of vessels in the fishing community is the total number of vessels whose harvest efficiency index rank is N or higher. Since the total number of vessels is related to the stickiness of the labor market and the Herfindahl index, from equation (11), another proposition can be established:

Proposition 2.

(1) $\dfrac{\partial \mu_N}{\partial \alpha} > 0$, $\dfrac{\partial \mu_N}{\partial \delta} < 0$, $\dfrac{\partial \mu_N}{\partial k} < 0$, $\dfrac{\partial \mu_N}{\partial p} < 0$, $\dfrac{\partial \mu_N}{\partial H} > 0$.

(2) if k>(<)k*, then $\dfrac{\partial \mu_N}{\partial \alpha} > (<) 0$.

(3) $\lim_{\gamma \to 0} \mu_N = 0, \ \lim_{\gamma \to \infty} \mu_N = \infty$.

The economic meaning of proposition 2-(1) is that value£g_N will decrease with increasing fish price, MSY, or fish stock growth rate, and increase with declining fixed fishing operation costs or fish market concentration. Lower values of £g_N will also result in an increase the optimal number of vessels in the fishing community. The Herfindahl index term further implies that the lower the variance of the fish harvest ratio, and the larger the total number of vessels in a fishing community, then the larger the optimal number of vessels.

Proposition 2-(2) states that stickiness in the labor market will only influence the optimal number of vessels determination in a fishing community when the MSY is above a certain threshold. To the extent that the MSY is larger than the specified value, labor stickiness¡]or flexibility of fishing cost¡^will be smaller (larger), and the optimal number of vessels will also be smaller. In other words, when the fish resources stock is relatively high, and the labor force can easily move in and out of the market, then the optimal number of vessels will be lower, and these vessels will on average have a higher fishing efficiency. The converse would also be true. These predictions appear to be consistent with the current inshore and coastal fisheries operations in Taiwan (Chuang and Lee, 1997). Proposition 2-(3) states that the optimal number of vessels in the fishing community is zero if the labor stickiness is relatively large, but this number increase as labor stickiness is reduced.

In the above analysis, the individual fishing activities of each vessel were assumed to be independent, and external effects – specially the impact that the number of vessels has on fish resource stocks – were not considered. However, to enhance the future development of the fishing community and ensure sustainable fish stocks, fisheries resources should be managed so as to maximize fishermen's long-term economic rents. This will be discussed in the next section.

3. Theoretical Model of Community-based Co-management

Assuming that co-management between fishermen's group and government will occur, and taking into account the external effect that fishing activity has on fish stock, then the fishermen's total profits can be maximized as followings:

$$\max_{h_i, b, N} \sum_{i=1}^{n} \left(p h_i - \frac{\beta h_i}{f(u_i) b} - \frac{h_i^2}{2\gamma f^2(u_i) b^2} \right) - \sum_{i=1}^{n} \alpha_i , \quad i = 1, \ldots, n \tag{12}$$

$$\text{subject to } \sum_{i=1}^{n} h_i = \delta b \left(1 - \frac{b}{k}\right).$$

Here, the decision-making variables are $h_i (i = 1, \ldots, n)$, b, and N. Implicit in equation (12) is the assumption that agreement between fishermen's organizations in the fishing community would not affect the fish price or the fish operating cost coefficient. The first-order conditions of equation (12) are

$$p - \frac{h_i}{\gamma f^2(\mu_i) b^2} - \lambda = 0 \quad i = 1, \ldots, n \tag{13}$$

$$\sum_{i=1}^{n} \frac{h_i^2}{\gamma f^2(\mu_i) b^3} + \lambda \delta \left(1 - \frac{2b}{k}\right) = 0, \tag{14}$$

$$\delta b \left(1 - \frac{b}{k}\right) - \sum_{i=1}^{n} h_i = 0. \tag{15}$$

Here, λ is the price of the available harvest. In long-run equilibrium, vessels with a fish harvest efficiency index rank of N can only expect to make a normal profit; in effect, N represents the available number of vessels in a fishing community, because vessels ranked after N would not pursue any fishing activities. Thus,

$$p h_N - \frac{h_N^2}{2\gamma f^2(\mu_N) b^2} - \alpha_N - \lambda h_N = 0 \tag{16}$$

From equations (13) to (15), after calculating we obtain

$$b^* = b_M \frac{2(\gamma k p H + \delta)}{2\gamma k p H + \delta} = b_M \left(1 + \frac{\delta}{2\gamma k p H + \delta}\right) \tag{17}$$

,

and

$$\frac{\lambda}{p}=\frac{\gamma kpH}{\gamma kpH+\delta}=(1-\frac{1}{\gamma kpH+\delta}). \qquad (18)$$

Equation (17) suggests:

Proposition 3. (1) $b^{*}>b_{M}$.

(2) $\lim_{\gamma\to 0} b^{*}=k>b_{M}$, $\lim_{\gamma\to\infty} b^{*}=b_{M}$.

Proposition 3-(1) implies that, from the point of view of integrated community development, when fishing activities are run under the community-based co-management, the optimal fish stock will be higher than MSY. This surplus of fish stock over MSY will increase with decreasing v (coefficient of variability of the fishing harvest ratio), P (fish price), and k (the environmental fish stock carrying capacity), or increasing δ (fish stock growth rate), γ (stickiness of labor market), and n (total number of vessels in the community). When the degree of labor stickiness in the market is quite large, it follows from proposition 3-(2) that the optimal fish stock of the community is twice the optimal fish stock under MSY. Conversely, when the labor force is relatively mobile, the optimal fish stock of the community is equal to the optimal fish stock under MSY. Moreover, from equations (16) and (9'), we have following proposition:

Proposition 4. (1)

$$b^{*}-b_{OA}=b_{M}(1-\frac{\delta}{2\gamma kpH+\delta})>0.$$

(2)

$$\lim_{\gamma\to 0}(b^{*}-b_{OA})=0, \lim_{\gamma\to\infty}(b^{*}-b_{OA})=b_{M}.$$

This proposition explains two things. First, from the point of view of the fishing community's integrated benefits, the optimal fish stock under the community-based co-management fishing structure would be higher than in the open-access fishery market. However, with increasing v, P, and, k and decreasing γ and n (total number of vessels in the fishing community), the differential between the two would diminish. Secondly, when the labor market is sticky, there would be no difference between b* and b_{OA}, whereas with the higher labor mobility, the difference between b* and b_{OA} would exactly equal to the fish stock under MSY. Combining propositions 3 and 4, it follows that when the stickiness of the labor market is quite small or the adaptability of harvest cost is quite large, from the perspective of integrated development in the fishing community, the optimal fish stock will be equal to the fish stock under MSY. This result, i.e. where the fish resource stock under MSY becomes the optimal choice of the fishing community, is quite different from the traditional model of fishery management, such as Chen (1994) or Matthiasson (1997). Remarkably, from the economic meaning of equation (18), we concur with Neher (1990), who said that in a regular labor market, the net price of caught fish, $p-\lambda$, i.e. the fish landing price minus the fish resource price in the sea, is positive. Of course, the difference between p and λ is also related to the stickiness of the labor market. This is expressed in proposition 5.

Proposition 5. $\lim_{\gamma\to 0}\frac{\lambda}{p}=\frac{1}{\delta}$, $\lim_{\gamma\to\infty}\frac{\lambda}{p}=1$.

Obviously, when labor stickiness is quite high or the adaptability of fishing cost is quite low, the price of the available fish stock may be higher than the price of the caught fish stock. Because δ represents the growth rate of the fish stock, $\frac{\lambda}{P}$ may, in general, be greater than 1. Conversely, with lower labor stickiness and high fishing operation cost adaptability, $\frac{\lambda}{P}=1$, and the net price of caught fish falls to zero. That is, the net price of a marginal quantity of fishing effort tends to zero, while maintenance of the optimal fish stock at MSY becomes reasonable.

So far we have discussed the economic implications on optimal fish stock, fish resource price, and fish market price. We now consider the optimum number of vessels under a community-based co-management fishery program. From equations (13), (16) and (17):

$$\mu_{N}^{*}=(\frac{2\alpha_{N}}{\gamma})^{\frac{1}{2}}(\frac{2\gamma H}{\delta}+\frac{1}{kp}) \qquad (19)$$

Equation (19) states that under the community-based co-management fishing structure, the catch efficiency index of the last vessel that will fish is μ_{N}^{*}. Again, the optimal number of vessels in the fishing community equates to those whose fishing efficiency is at rank N or before. Combining equations (19) and (11), we obtain

Proposition 6. (1) $\mu_{N}^{*}-\mu_{N}=\frac{(2\alpha_{N})^{1/2}H}{\delta}>0$.

(2) $\lim_{\gamma \to 0} \mu_N^* - \mu_N = 0, \lim_{\gamma \to \infty} \mu_N^* - \mu_N = \infty$.

Proposition 6 states that the optimum number of vessels under the community-based co-management scheme is lower than that under the open-access fishery. In other words, the open-access fleet would include vessels with relatively lower fishing efficiency.

Proposition 6 also shows how stickiness in labor market affects the difference between μ_N^* and μ_N. As implied by previous propositions, when the labor market is quite sticky, μ_N^* and μ_N are the same, but the difference between μ_N^* and μ_N becomes significant as labor mobility increases.

Having shown how factors like labor stickiness, the Herfindahl index and fish resource stock conditions affect the optimum fish stock and the optimum number of vessels, in the next section, simulated values will be applied to the static comparative results and the implications discussed.

4. Simulation Analysis

The derivatives of the optimal number of vessels are determined from the harvest efficiency index array. Thus, the upper limits of the optimal number of vessels are given by μ_N^* and μ_N in value simulations that we use different Herfindahl index values within a fishing community. Upper bound definitions are as follows:

Definition 1. Under open-access conditions, the upper bound on the optimal number of vessels is $\overline{N} = \frac{H}{\mu_N^2}$.

Definition 2. Under a community-based co-management scheme, the upper bound on the optimal number of vessels is $\overline{N}^* = \frac{H}{\mu_N^{*2}}$.

Definitions 1 and 2 represent the upper bound of optimal number of vessels under a specific Herfindhl index, if every vessel's fishing efficient index is equal to μ_N or μ_N^*. Since μ_N and μ_N^* both represent the last vessel with normal profits, and all other vessels with excess economic profits have fishing efficiency index larger than μ_N or μ_N^*, the vessel number obtained from calculating $\frac{H}{\mu_N^{*2}}$ or $\frac{H}{\mu_N^2}$, would be more than the sum of squares of all harvest efficiency index higher than μ_N or μ_N^*. That is why the vessel number obtained from definition 1 and 2 were claimed the upper bound of the optimal vessel number.

For the simulation, we follow the methods of Bierman and Fernandez (1993) and Conrad and Clark (1987). Data values are:

k=100,000; δ=0.2;P=0.5; γ =0.01;H=0.005. Here, H is given a relatively low value because fishery sector approximates market conditions that are perfectly competitive. Conversely, in an oligopoly, H is normally greater than 0.1. For example, the Taiwanese domestic cement market in 1989 had a value of 0.14 and for the domestic movie market in 1995 H=0.10 (Chen, 1993 and Won et al. 1998).
Applying the above values to the appropriate equations yields the following simulation results:

Result 1:
b_{0A}=794; b^*=50,199; μ_N =0.0042; μ_N^* =0.0078; $\overline{N}$ =278; $\overline{N}^*$ =83.

Holding other parameters constant, and varying γ and H yield the static comparative results shown in Table 1.

Result 2: under a specified value of H, as labor stickiness decrease, b_{0A} and b^* tend to decrease, while $\overline{N}$ and $\overline{N}^*$ first increase and then decrease.

Result 3: (1) When the degree of labor stickiness is large (γ =0.0001), as H increase, b_{0A} and b^* decrease, while $\overline{N}$ and $\overline{N}^*$ increase.

(1) When the degree of labor stickiness is relatively small (γ =0.1 or 1), as H increase, b_{0A}, b^*, $\overline{N}$, and $\overline{N}^*$ all decrease.

Result 4: With decreasing labor stickiness and increasing H, $b_{0A} - b_0^*$ increases, while $\overline{N}^*$ - $\overline{N}$ decrease.

Table 1: Static comparison with different γ and H value

γ	H	b_{0A}	b^*	$b^* - b_{0A}$	μ_N	$\overline{N}$	μ_N^*	$\overline{N}^*$	$\overline{N} - \overline{N}^*$
0.0001	0.001	80000	83333	3333	0.0071	19	0.0072	19	0
0.0001	0.0025	61538	72222	10684	0.0072	48	0.0074	45	3
0.0001	0.005	44444	64286	19841	0.0074	91	0.0078	83	8
0.0001	0.01	28571	58333	29762	0.0078	165	0.0085	139	26
0.0001	0.02	16667	54545	37879	0.0085	278	0.0099	204	74
0.001	0.001	28571	58333	29762	0.0025	165	0.0027	139	26
0.001	0.0025	13793	53704	39911	0.0028	320	0.0034	222	198
0.001	0.005	7407	51923	44516	0.0034	444	0.0045	250	194
0.001	0.01	3846	50980	47134	0.0045	500	0.0067	222	278
0.001	0.02	1961	50495	48534	0.0067	444	0.0112	160	284
0.01	0.001	3846	50980	47134	0.0014	500	0.0021	222	278
0.01	0.0025	1575	50397	48822	0.0025	408	0.0042	139	269
0.01	0.005	794	50199	49406	0.0042	278	0.0078	83	195
0.01	0.01	398	50100	49701	0.0078	165	0.0148	45	120
0.01	0.02	200	50050	49850	0.148	91	0.029	24	67
0.1	0.001	398	50100	49701	0.0025	165	0.0047	45	120
0.1	0.0025	160	50040	49880	0.0058	74	0.0114	19	55
0.1	0.005	80	50020	49940	0.0114	38	0.0226	10	28
0.1	0.01	40	50010	49970	0.0226	20	0.0449	5	15
0.1	0.02	20	50005	49985	0.0449	10	0.0897	2	8
1	0.001	40	50010	49970	0.0071	20	0.0142	5	15
1	0.0025	16	50004	49988	0.0177	8	0.0354	2	6
1	0.005	8	50002	49994	0.0354	4	0.0708	1	3
1	0.01	4	50001	49997	0.0708	2	0.1415	0	2
1	0.02	2	50000	49999	0.1415	1	0.2829	0	1

Results 2, 3 and 4 suggest that when there are no labor mobility barriers, then with larger values of H, the optimal number of vessels and the fish stock would be smaller. To maintain a relatively larger optimal number of vessels and fish stock, the degree of mobility in the labor market has to be around medium (r~0.001-0.01). Larger values of H, i.e. the more inequality in the vessels' fish market share, and greater differentials in the fishing harvest efficiency index in the fishing community also result in relatively fewer vessels and fish stock. Conversely, low H and small differentials increase vessel numbers and fish stock. Finally, as to the impacts of changing fish stock growth rate and fish price on the optimal vessel number and fish stock can be derived following these processes.

5. Conclusion

In recent years, resource depletion of inshore and coastal fisheries has seriously impacted Taiwan. Local fishing communities' economic activities in these fisheries have declined and this has resulted in lower earned incomes for the fishermen. These phenomena have led many scholars, government agencies and fishing communities to evaluate the optimal number of operating vessels in these fisheries. Furthermore, as community consciousness has risen, fishery resource management has shifted from government-led to co-management between central government and the fishing communities themselves. This study has explicitly applied the concepts of co-management, fish market concentration and labor stickiness to an economic model that can be used to determine the optimal number of fishing vessels in a fishing community. Simulation results suggest that when there are low labor mobility barriers, then with larger values of H, the optimal number of vessels and the fish stock would be smaller. In order to maintain a relatively larger optimal number of vessels and fish stock, the degree of labor mobility should be around the medium level. The more inequality in the vessels' fish market share in the fishing community also result in relatively fewer vessels and fish stock. Conversely, low H and small differentials in harvest efficiency increase vessel numbers and fish stock. This model results suggest that changes could usefully be made in the Taiwanese ACC's current policy whereby the retirement of old vessels is speeded up. The ACC's vessel buyback program assumes that old vessels have a lower fishing efficiency, but does not take the fish market or the labor market into account. From the point of view of co-management, a more adequate purchasing procedure should consider market conditions and the constraints imposed by limited fish resources, and then set purchasing priorities accordingly. We propose here that vessels without any fish market share, i.e. those that are not engaged in fishing activities and vessels with a low fish market share are the ones should be purchased. On the other hand, regardless of age, those vessels that engaged in high enough fish market share would not be purchased.

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