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Fishery Collapse with Two Periods Analysis in Dong Jiang Lake

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Abstract

We develop a theory of fishery management where the time span can be divided into two periods to explain fishery collapse in developing countries. In the initial exploitation period, government does not take actions to manage fishery in that government lacks of information and needs to take time to gather information, and actions. Fishers catch as much as possible. Fishery is collapsed quickly. In the second period, government chooses little management as optimal choice for the government self short term revenue goal. So fishery is always collapsed and no chance for recover. Eventually fish is exterminated as technology advance. Dong Jiang Lake is such a case.

Keywords: Government self-interest, free entry, fishery collapse, two periods

Many of the world's major fishery' resource stock are going to decline, particularly in developing countries (Myers, & Worm, 2003; Beddington, Agnew, & Clark, 2007; Sumailia, 2010). Since Hardin (1968) popularized the concept "tragedy of the commons (TOM)", the concept is accepted widely, even the concept is used in finance (Hassan, & Mertens, 2011). One way to overcome of the tragedy is resorted to clear property, or private property and state property (Hardin, 1968). Although the limits of TOM or ITQ also are concerned (Bromley, 2009; Rouba, A., 2009; Clark, Munro, & Sumaila, 2010; Lam, & Pauly, 2010), no doubt, this opinion explains why the private property right is so prevailing in the current world. But in private status, actually, there is numerous resources collapsed or collapsing. Traditionally assuming, explicitly or implicitly, that the objective of government is maximization of social welfare (Solow, 1974; Mardle, & Pascon, 1997; Graton, Kompas, & Hibbon, 2007; Sumaila, 2010), however, the realty may be not true in developing countries while this traditional view should be corrected practically in that the government as a rational economic agent has self-focus in which pursuing maximization revenue is the most common one.

Government failure may be unintentional for ignorance, lack of decision information. It may be caused by laws which are erected immaturely and are so ambiguous or infeasible that trigger vast transaction cost, for example. And some times this failure can be corrected by informal rules from external groups. Ostrom (1990) emphasizes that rule legalized by local communities by the users are essential in a successful resource management system. From the ancient to the modern, this kind of organization acted as rule guards when it was absence of powerful government. Even now in undeveloped backwater the informal rules are effective. Without doubt, many fisheries operate in such way. But if without external rules whether formal or informal, control the operation behaviors, then effective cooperation between fishers may be another effective method to get away the dilemma.

Another aspect for the government failure may be intentional for office' self goals. Government as an economic agent may choose resource collapse as an optimal action. Because it should be constrained by the budget and balanced the return and cost in the resource management, so the government may achieve a goal contradicted with whole social welfare. In the fishery management, the literature (Clark, 2000, 2010) often captures the ideas. But it often considers optimal actions for fisheries exploited for many years, even collapsed fisheries (Copend & Taylor, 2009), and ignores to examine carefully the effect of initial choices of government on the following construction of management system when a fishery is just utilized and is conserved well at its potential capacity stock. That is, there is asymmetric information about the knowledge of the fishery for the government and fishers and fishers have incumbent advantages.

In developed areas, it is no problem to carry over a rule whether informal or formal for the social welfare in that the government is representative of the common. In the developing country, however, like China, the laws can have apparent propensities to favor the individual office and sacrifice common's interest. In China, for without independent system of legislative power and jurisdiction, government can do anything if she wants. So, it is not surprise that the social welfare may be trampled. Fishers may not trust government. And fishers lack of the convenient channel to effectively communicate with government for reach cooperation, for example, reconcile the conflict and rearrange the fishing amount, if little trust. Additionally, the short tenure and accountability to the superior of office indirectly causes that high discount rate becomes the sensible selection for fishers and government.

As many countries or areas that experience fishery collapse, but unlike in China, more than 90% fisheries in the lakes, or rivers, whose area surfaces are small than 160 square kilometers and initial capacity is small, are collapsed. Without any question, the government' adverse management objective should be the main reason. In this paper, we try to answer this interesting question, illustrating Dong Jiang Lake as an example.

The rest of the paper organizes as following: In section 1, we set out two models, the social welfare maximization model and the office welfare maximization model. In section 2, we introduce applications background, Dong Jiang Lake in detail. In section 3, we compare models' simulation outcomes with the real facts to check aptitude of the theory, and in section 4 discuss how our results would change if certain assumptions are changed. Section 5 concludes.

1. Model Introduction

In our theory, we only consider the local equilibrium. Although general equilibrium may be a better way, the two methods get the similar conclusions. We consider a small open economy in which there are two kind agents, fishers which are identical and are representative by one agent, and government which acts as an independent economic unit working for the whole social welfare or only for the office's self welfare. All markets except the fish market are completely competitive and fixed prices, or no one has market power. But buyers have market power in the fish market. Particularly, the price of fish is determined by oligopolies. Except the fishery no industry can create any job. That is, fishers own zero opportunity cost in that in our paper fishing operations occur at night, so lacking of other substituting opportunities. The prices of fish are taken as given exogenously for fishers' perspective. In the fishery in which fish is exploited by the native and except that, the other influence is only from government, it has two different kinds of pelagic fish species, ice fish, x, and white fish, y. Although it may be notation absurd, we let x and y not indicate the nature resources but also the stock of the resources. There are two models. The first one is the socially optimal model, presuming resource managed by a benevolent dictator who constrains the catch efforts, seeks the whole society welfare maximization and let fishers hold all surpluses. The second is examined under control by government whose objective is to acquire maximizing office revenues. And the fishers' objective is to obtain maximal individual utility. While the ecology is a complicated system we focus on two main economic species, which may be instructive from the economic view and be identical with situations.

1.1 Social Welfare Model

The first model is to maximize the social welfare and all the Marshall surpluses are contributed to fishers. So we can ignore government and only focus on the fisher agents. Tastes are homothetic; hence the indirect utility function can be written as a function of real income, following by risk neutral and taste is homothetic. We denotes by *R(t)* the instantaneous net income flow from fishery working for an agent at time *t*. Additionally, we assume that fisher agents can live forever. The time discount rate is θ a constant. Then the expected present discount value of life income V_s for a representative fisher becomes

$$V_s = \int_0^{\infty} e^{-\theta t} R(t)\, dt \quad , \tag{1}$$

Harvesting from resources depends on effort, the prevailing stock and the catch ability. The resource stock is distributed uniformly. The catch abilities are constant. We adopt the commonly used catch-effort

$$h_x = q_x e_x x \,, \quad 0 \le e_x \le e_{\max} \tag{2}$$

$$h_y = q_y e_y y + q_x e_x y \,, \quad 0 \le e_y \le e_{\max} \tag{3}$$

where subscripts x and y indicate the resource x such as y; h_x and h_y are the harvesting of resource x and y respectively; e_x and e_y are harvesting effort and e_{max} is the up bound of harvesting effort; q_x and $q_y$are the catch ability. The difference between equation (2) and (3) may be the second term $q_x e_x y$ in the right of equation (3) which implies that harvesting input for exploitation x can also catch incidentally resource production y and but harvesting input for exploitation y can also catch incidentally resource production x. It is referred as partial non-selective exploitation. In words, the effort to capture ice fish can catch ice fish and white fish. But the effort to capture white fish can catch white fish and does not catch white fish. We adopt the Worm and Myers (2003) definition of collapse that a fishery is considered as collapsed in year t if the harvest in year t is <10% of the maximum recorded harvest up to year t.

We adopt the logistic growth model (Clark, 2010), combined with partial non selective fishing model mentioned above, and the state equations for x and y can be given by

$$dx = (\gamma_x x(1-\frac{x}{K_x}) - q_x e_x x)dt \tag{4}$$

$$dy = (\gamma_y y(1-\frac{y}{K_y}) - q_y e_y y - q_x e_x y)dt \tag{5}$$

Where γ_x and γ_y denote the intrinsic rate of resource growth, K_x and K_y are carrying capacity, and assume that $\gamma_x > \theta$, and $\gamma_y > \theta$ for pelagic creature often has the high productive rate.

The cost functions for harvesting x and y can be given by

$$C_x(e_x) = c_x e_x,\ \ C_y(e_y) = c_y e_y \tag{6}$$

Where e_x and e_y are the harvesting effort of resource x and y respectively. And c_x and c_y is constant cost of unit effort.

The equilibrium prices of fish market are determined by monopolies and fisher agents act as prices taker. We think the fish price as following,

$$p_x(x) = p_x,\ p_y(y) = p_y \tag{7}$$

Combined with equation (1) to equation (9), we get a comprehensive model,

$$\begin{aligned}
&\underset{\{e_x\ e_y\}}{\text{maximze}} V_s = \int_0^\infty e^{-\theta t} R(t)dt = \int_0^\infty e^{-\theta t} p_x * h_x + p_y * h_y - C_x - C_y)dt \\
&\text{s.t.} \quad \frac{dx}{dt} = \gamma_x x(1-\frac{x}{K_x}) - q_x e_x x \\
&\qquad \frac{dy}{dt} = \gamma_y y(1-\frac{y}{K_y}) - q_y e_y y - q_x e_x y \\
&\qquad 0 < \mu < 1 \\
&\qquad 0 < \theta < \gamma_y \qquad 0 < \theta < \gamma_x \\
&\qquad 0 < e_x \le e_{\max} \qquad 0 < e_y \le e_{\max} \\
&\qquad 0 \le x \qquad x(0) = x_0 \\
&\qquad 0 \le y \qquad y(0) = y
\end{aligned} \tag{8}$$

The Hamiltonian is

$$\begin{aligned}
\mathrm{H} = {} & e^{-\theta t}(p_x e_x q_x x + p_y e_x q_x y + p_y e_y q_y y - c_x e_x - c_y e_y) \\
& + \lambda_x(\gamma_x x(1-\frac{x}{K_x}) - q_x e_x x) \\
& + \lambda_y(\gamma_y y(1-\frac{y}{K_y}) - q_x e_x y - q_y e_y y)
\end{aligned} \tag{9}$$

We define the following two equations as switching functions for x and y

$$\sigma_x(x,t) = e^{-\theta t}(p_x q_x x + p_y q_x y - c_x) - \lambda_x(q_x x - \lambda_y q_x y) \tag{10}$$

$$\sigma_y(y,t) = e^{-\theta t}(p_y q_y y - c_y) - \lambda_y q_y y \tag{11}$$

$$\lambda_x = \frac{\partial V}{\partial x} > 0, \quad \lambda_y = \frac{\partial V}{\partial y} > 0 \tag{12}$$

The above model is the linear bio-economic model. The equilibrium is bang-bang control, stable and unique,

$$e_x = \begin{cases} 0 & \text{if } \sigma_x(x,t) < 0 \\ unspecifed & \text{if } \sigma_x(x,t) = 0 \\ e_{\max} & \text{if } \sigma_x(x,t) > 0 \end{cases} \tag{13}$$

$$e_y = \begin{cases} 0 & \text{if } \sigma_y(y,t) < 0 \\ unspecifed & \text{if } \sigma_y(y,t) = 0 \\ e_{\max} & \text{if } \sigma_y(y,t) > 0 \end{cases} \tag{14}$$

By equation (13), if $\sigma_x(x,t) < 0$ then the resource x should not exploit at all. When the resource stock is too low, the exploitation is not an optimal decision low and the resource can keep reservation without any exploitation. However, if $\sigma_x(x,t) > 0$ then the resource x should exploit at the maximum harvesting speed. This phenomena happen frequently when a new valuable resource is been discovered. The equation (15) can be analyzed similarly.

If $\sigma_x(x,t) = 0$ or $\sigma_y(y,t) = 0$ solutions become singular solutions. Assuming existing internal singular solution, we can obtain the following equations (15) and (16) for optimal stock x^* and y^* respectively at the equilibrium status, equation (17) and (18) for optimal effort, and the superscript * denotes the social optimality

$$x^* = \frac{-p_x\theta - (\frac{c_y}{q_y} - \frac{c_x}{q_x})\frac{\gamma_x}{K_x} + p_x\gamma_x + \sqrt{(p_x\theta + (\frac{c_y}{q_y} - \frac{c_x}{q_x})\frac{r_x}{K_x} - p_x\gamma_x)^2 - 8\frac{p_x\gamma_x\theta}{K_x}(\frac{c_y}{q_y} - \frac{c_x}{q_x})}}{\frac{4p_x\gamma_x}{K_x}} \tag{15}$$

$$y^* = \frac{-p_y\theta + \frac{c_y\gamma_y}{q_y K_y} + p_y\gamma_y + \sqrt{(p_y\theta - \frac{c_y\gamma_y}{q_y K_y} - p_y\gamma_y)^2 + 8\frac{p_y\gamma_y c_y\theta}{K_y q_y}}}{\frac{4p_y\gamma_y}{K_y}} \tag{16}$$

$$e_x^* = \frac{\gamma_x(1 - \frac{x^*}{K_x})}{q_x} \tag{17}$$

$$e_y^* = \frac{\gamma_y(1 - \frac{y^*}{K_y}) - \gamma_x(1 - \frac{x^*}{K_x})}{q_y} \tag{18}$$

We can immediately conclude that if $c_y = p_y q_y v^*$, then $y^* = K_y$. The intuition is simply that when the cost equals the benefit, the resource would not be utilized. If the c_y is zero, equation (16) simplify

$$y^* = \frac{1}{2}K_y(1 - \frac{\theta}{\gamma_y}) \tag{19}$$

Equation (19) means that if the discount rate is $\theta = 0$, stock of resource is $y^* = (1/2)K_y$ which can just lead to the maximum sustained yield. If discount rate is bigger that natural growth rate $\theta \geq \gamma_y$, let economically exterminate resource $y^* = 0$. If growth rate is smaller than discount rate $0 < \theta < \gamma_y$, we can find optimal resource stock is less than MSY $0 < y^* < (1/2)K$. When analyzing with the asset pricing theory, the explanation is well behaved. If the asset' growth rate γ_y exceed the conserved growth rate θ, then the owner would keep the asset. Otherwise, the owner would dispose the asset and invest the capital to the other assets. When we let $c_x = c_y = 0$, the analysis of equation (15) can get the analogous results. The resource natural growth rate is the essential factor in determining the optical resource stock. In this paper, we discover that the both fishes have no-low productive rates. From equation (15) and (16), the more speed resource natural growth, the high level of resource optimal stock.

It can be easy to understand that if marginal cost exceeds marginal revenue $c_y \geq p_y q_y y^*$, and switch function less zero $\sigma_y(y,t) < 0$, the resource y keeps resource un-exploitation. The behavior of resource x has difference with y. When $c_x > p_x q_x x^* + (c_y q_x / q_y)$, the resource x can be conservation completely. But if the marginal cost of harvesting resource x exceeds the marginal revenue $p_x q_x x^* < c_x < p_x q_x x^* + (c_y q_x / q_y)$, the exploitation should be paused if the effort e_x can only influence production of x, or the non-selective fishing does not existing. But under the non-selective exploitation, the utilization should continue in that the byproduct with the operation of x can bring the additional revenue to compensate the cost caused by the production of x. In reality world, it is very common in nature resource exploitation process. The iron ore industry, for example, is a typical case. The waste of refining may contain other valuable metals, but the amount of them may be relative small, such as the zinc, copper, or nickel. Given $c_x =< p_x q_x x^* + (c_y q_x / q_y) > p_x q_x x^*$, the effort of e_x becomes more aggressive compared without the non-selective exploitation

The explanation of θ can not be apparent. From equation (15), if discount rate is zero $\theta = 0$, the stock of resource is

$$x^* = \frac{1}{2p_x}\left(\frac{c_x}{q_x} - \frac{c_y}{q_y}\right) + \frac{K_x}{2}$$

which seems that the stock of resource x may be collapsed, or even exterminated if marginal cost c_y is significant huge compared with marginal cost c_x. In words, exploitation of resource x may have comparative cost advantage. From equation (16), however, if discount rate is zero $\theta = 0$, the stock of resource

$$y^* = \frac{K_y}{2} + \frac{c_y}{2p_y q_y}$$

is only related with marginal cost c_y. On the extreme direction, if discount rate is infinity $\theta \to +\infty$, the resource system should be collapsed or even resource should become extinct. In the section 3, we adopt a high discount rate for the government's inappropriate intervening. And this may reduce resource stock, eventually dissipate rent.

Exploitation of only resource x may be an optimal choice if resource relative stock $\frac{x}{K_x}$ is low but resource natural growth rate γ_x is high. Therefore all the investment may be contributed to the effort e_x and investment for effort e_y may be zero, from optimal economic perspective. It also exist the market for resource y for the non-selective fishing technology.

Combined with above analysis outcomes, we can get the net profit,

$$p_x q_x x^* + p_y q_x x^* > C_x, \quad p_y q_y y^* > C_y \tag{20}$$

In the model, the net profit is not zero in that we assume that government maximizes social welfare.

1.2 Office Welfare Model

In the second model, the government manages the fishery for the self revenue maximization. Whether the fishery may be free entry model or may be limited entry, depends on the way which government can achieve its objective. In China, office has an extremely high discount rate for the short tenure. The fact that the optimal choice may be let the fishery is free entry for in the initial exploitation period, can be caused by two reasons. Firstly, the monitoring cost is so unaffordable for the government that free entry is an inevitable selection. The second reason may be that the government tries to obtain as much revenue as possible in the shortest time because the office's tenure is only four years. The way to gather revenues in fishery is often fine. And in the fine proceed, there always is full of violence. Combined free entry and violence, the discount rate is increasing sharply. Every agents, office and fishers, all are bond in the competitive game. Besides, we also assume that agents are risk neutral and tastes are homothetic. The utility function can be written as the real income function. The objective of a fisher is given

$$\max_{e_y e_x} V_p = \mu R(t) = \mu(p_x h_x + p_y h_y - c_x e_x - c_y e_y)$$
$$= p_x q_x e_x x + p_y q_x e_x y + p_y q_y e_y y - c_x e_x - c_y e_y)$$
$$\text{s.t.} \quad \frac{dx}{dt} = \gamma_x x(1 - \frac{x}{K_x}) - q_x e_x x$$
$$\frac{dy}{dt} = \gamma_y y(1 - \frac{y}{K_y}) - q_y e_y y - q_x e_x y \tag{21}$$
$$0 \le e_x \le e_{\max} \qquad 0 \le \mathrm{e_y} \le e_{\max}$$
$$x \ge 0 \qquad x(0) = x_0$$
$$y \ge 0 \qquad y(0) = y_0$$

where notations are the same as the above part, and μ is a fine index reflecting deprivation of fishers by the government.

From the equation (21), we know that the optimal equilibrium solutions x^0 and y^0 are stable and unique, and superscripts ^{0} denote optimal solutions in the office welfare model.

$$x^0 = \frac{c_x}{p_x q_x} - \frac{c_y}{p_x q_y} \tag{22}$$

$$y^0 = \frac{c_y}{p_y q_y} \tag{23}$$

$$e^0{}_x = \frac{\gamma_x (1 - \frac{c_x}{p_x q_x K_x} + \frac{c_y}{p_x q_y K_x})}{q_x} \tag{24}$$

$$e^0{}_y = \frac{\gamma_y (1 - \frac{c_y}{p_y q_y K_y}) - \gamma_x (1 - \frac{c_x}{p_x q_x K_x} + \frac{c_y}{p_x q_y K_x})}{q_y} \tag{25}$$

We can proceed to analysis about the solutions using the above analysis method and result in the general economic significance. If resource exploitation cost were increased, for example, then the resource stock would be increased and the effort would be decreased.

Government acting a rational economic agent constrained by the fiscal budget tries to maximize punishment revenues, which is a very common method to enhance office income in China. As before, we assume that the government is neutral reversion and taste is homothetic. Additional, we assume reasonably that if government can not obtain the net income then the activities such as petrol would be stopped and the fishery becomes of anarchy. The utility function is given by

$$\max V_g = \mu R(t) - c(t)$$
$$\text{s.t.} \quad 0 < c(t) < \infty \tag{26}$$
$$0 < \mu < 1$$

where *R(t)* is the income flow of representative fisher, μ is a fine index reflecting deprivation of fishers by the government, and c is the cost. The solution is $\frac{\mu dR(t)}{dt} = \frac{dc(t)}{dt}$, marginal benefit equals marginal cost.

It is inferred that at the initial exploitation stage, or before stable equilibrium, the rent may be positive and government can gain fine revenues management. But after that period, the rent becomes zero and the government has no incentive to control the free entry. So no management is optimal. If the government's objective were social welfare maximization, the government should let the resource to equilibrium as soon as possible without any interference and then take action avoid the common tragedy. But it is not for the rational self-interest government.

2. Model Application Background –Dong Jiang Lake

In this section, we use the Dong Jiang Lake as an example in that the Lake is a typical resource in China. And 10 years ago, the fish stock was in very high status and now is seriously decreased, or the fishery is collapsed. The observation is representative. We take a year to investigate and examine the various economic parameters.

The Lake was built 27 years ago fund by government. Like many artificial lakes in China, the main objective is to provide electricity to Beijing-Kowloon railway which connects the south and the north of China and is an extremely vital transportation infrastructure. That is, the fish resource was not on the agenda of government when the Lake was programmed. So it is not surprising that at a very long time the Lake's fish resource is under no control situation. After the Lake built ten years, however, the local government began to interference the fish resource.

In Dong Jiang Lake, the main commercial fishes are ice-fish and white-fish which were introduced by a private commercial firm in 1994. The firm had secretly contracted with government and pay a rent about 2 million for the using right of the Dong Jiang Lake in 20 years. But after five years, a fisher occasionally discovered that valuable species and the catch method.

Ice-fish is high valuable in China. Its' habitat is in fresh and high quality water and lives on plankton in the upper water. For Ice-fish would die immediately if it leaves water over 10 second, so the whole ice-fish should be baked by the sunshine within at most four honors when the fish leaves the water. The fishing procedure is so simple and convenient that there is no cumulative human resource capital in the fishing operation. Simply speaking, the fish apparatuses consist of a net, a steel wire, a bulb, a lever and a boat. Fishing happens at night limited by the catch method. Fishers must build a lighting foothold by which the bulb can be firmly bound to avoid drop into water by natural wind or rain force. Firstly, two fishers sink a net into water ground. The net's arbitrary two closest corns should be fasted into the level by the steel wire and the other two close corns should also fasted into the land in the adverse direction; then light the bulb to attract the fish; next, wait quietly, until fishers believe that enough fish staying up the net. Then, fishers push the net to the water's surface and catch fish by boat. The fishers can do it again if they want fish another time.

Besides the ice-fish, the white-fish is also the main commercial fish. Traditionally, whitefish is the popular and enjoyed food. It is a kind of long life creature living on other small fishes and living in upper water. It can averagely lengthen to 20 cm and weight 0.5 kg, after a year's growth. And at the ideal condition, a fish can grow over 100 kg. Catching the white-fish is similar to catch ice-fish. Yet, the net using to capture the white-fish was two times big to ice-fish. In a world, the size of white-fish's apparatuses is large scale. The net can not use to catch ice-fish and but a net for catching ice-fish can use to catch white-fish in that the eye of net for ice-fish is smaller than the eye of white-fish net.

The surface area of Dong Jiang Lake is about 160 square kilometers and there are over five hundred dispersed full employment fishers and orange plantation, so impossible is it to get the exact data, such as potential production and catch rates. But for fishers' identical behaviors, we can get the appropriate results by investigation a village, Gaopu. The village, Gaopu is surrounded by the water located in the middle of Lake. There are 412 natives who not only lived in the island but also earned the income by orange and fishery, from 2000 to 2010. Among the natives, there are 7 people which are full-employment in the orange plantation and fishing. The observation number of the sample may be small. We guess, however, it can be representative of the fishers and orange farmers. And in 2000 to 2003, in Gaopu village, there are about 350 adult men enjoyed full employment in fishery and orange plantation. The observations of 7 people may be selective. But we discover that catching the ice and white fish is a low technologic job, the difference of fishers' behavior is trivial and it is other causes for example conveniently taking family members that lead the 7 people to continuing fishing. Resulting of the sample is efficient.

2.1 Fishers and Inhabitants

There are two main income sources of inhabitants in Dong Jiang Lake, fishing and orange plantation. The orange plantation is the most critical backbone of every family in Dong Jiang Lake. In 2010, however, there are only less 5% families living near Lake whose income from the fishing is indispensible. To a fishing family, the percentage of orange income in total income may be over 60%, fishing about 30%, other approximately 10%, averagely. The labors of orange plantation enjoy leisure from February to October, and in the rest time of the year, all inhabitants, fishing family or non-fishing family, are busy in selling the orange on time in that the ripe orange will be rotted worth nothing and most orange is ripe within November and December. Another inevitable element is the low risk of orange plantation and high risk of fishing. The months of fishing begin April and end November, together 8 months. In cold winter and spring, fish can hide and be inactive so it is not economic feasible to operating fishing in winter. In a word, the cost of poaching fish resource is cheap if government forbids illegal fishing.

The chances of employment in non-farm job at night are seldom. Consequently, Two choices are existing, either absolutely un-productive entertainment or relatively low productive fishing. Assuming fishers are identical can be effective in that by investigation we know that every fisher has the same attitude to consumption, deposition and investment. Except the necessary family daily expenditure, like the salt, oil, there conserve all the money for children's education and marriage. The native keeps the simple life style. So we can presume that fishers' utility function can be denoted by income.

Every fisher comes from the local native, and lives near the bank of Lake, because the fishing can be limited by apparatus. In detail, fishing needs electricity and every fisher uses self-home electricity, so if homes do not near the bank, then one maybe lack the basic condition to the fishing occupation. But if outsiders want to fish, no one will be prevented if the one has sufficient conditions. But in our interview, we can not find any outsiders.

2.2 Fish Prices

In Dong Jiang Lake, the number of fisher is at least half thousand. On the supply part, every fisher provides the approximately same amount of fish averagely. On the demand part, the number of wholesales is relative small. And if it is not apt to say that the wholesales can form a monopoly organization and completely control the price, it is affirmative that the wholesales can effectively influence the price. One reason is that Dong Jiang Lake's fish has the high quality and is distinguished amongst the customers.

In this paper, the price is referred only in terms of fishers or to the primitive market not to the second market or other retail market. Real prices of ice-fish and white-fish show stationary in a given period. The price can be divided into two periods and 2005 can seem a turning point. The population of both fish was exploited originally in 2000. Because it was not exploited before 2000, the production at that time was extremely high but the price was relative low compared with 2010. From 2000 to 2004, the price of ice-fish was per kg 5 dollar and the white-fish per kg 1.2 dollar. After an initial uncontrolled exploitation, the resource becomes collapsed, and since 2005 the price of ice-fish is 20.0 dollar and 2 dollar, and it maintains until now. But in the investigation, we know that even the price becomes high, the income of fishing is decreasing. And a simple indication can be justified, that in 2000, almost all male natives worked in the fishing and the investment was fueled. But since 2005, only the 2% or 3% fishers remained who live on fishing since youth and maybe in the whole life time. We did not say that the remaining fishers are most skilled but only the lowest opportunity cost for some reasons in that they lack the abilities to find the higher income alternative jobs.

2.3 Fish Growth Rates

The growth rate of ice-fish is relative high. Its spawning months are December and January and incubation months are January, February, and March. Note that at that time the commercial fishing is paused in that in one side fishers are busying in selling orange and has no time, and in another side, fishing becomes very dangerous for losing lives for frequently windy cold weather in winter. So it becomes a convention that fishers may not catch ice-fish in these months. It is this catching convention that protects the ice fish' high productive rate.

One of adult ice-fish can produce 2500 roes, in common. In wildlife, there are many undesirable conditions, such as the low temperament, strong wind, and other adverse human interference. While about 80 % of it can be hatched successfully in the ideal experiment condition, at most only 40% of roes can be incubated achievably. Only a few of recruit, less 1% remaining can grow into ripe for many predators in the Lake. Natural growth rate is per year 0.8 more or less. Compared with other species, like the Antarctic blue whale, the rate is significant high. We also suggest that it is the high reproduction rate that lead to the ice-fish being surviving after an intensive exploitation.

The phenomenon that the ice fish can keep a high level of growth rate can largely be contributed to nature and we believe it can be maintained in the long time if the catch technologies can not be transformed in the short period. It may be true because some commercial organizations failed to exploit the ice fish by using the high technologies, for example the trawl, for the high cost of operation and low capacity of production.

The growth rate of white-fish is much lower that the rate of ice fish. After two or three year growth, it can become an adult fish and have the productive ability. The reproduction season of white fish is in March, April and May. In wild environment, an adult white fish can produce between 5000 and 10000 roes, which are very high for the large shape of white fish. But only 30% of them can be incubated successfully. Under more predators, less 0.1% of remaining can be grown into adults in nature. But adding other severe conditions the growth rate of white fish is about 0.2 per years.

There are two reasons for explaining the low growth rate for white fish. One is that the reproduction period coincides with reproduction periods of many kinds of fishers, like carp, when the ecology system of the Lake are high variable and predators' action are extremely intensive, so the nature reproduction loss occupies a large percent. Another reason may be that in that period the poaching is prevailing and some parents fishes may be captured unlawfully. Particularly, in the human exploitation process, the destruction of incubation places and reproduction location is unavoidable. The latter' influence may be disastrous. But fortunately, the trawls are not being adopted. So the destruction does not influence incubation places in the deep water. The source-sink effects still are effective.

2.4 Fishing Cost

The fishing cost can be classed into two categories, fix cost and variable cost. Except the difference of the fish net, the other materials for fishing ice and white fish are same. Consequently, to some extend, the fisherman can easily exchange the fishing goals between the ice fish and white fish, without much additional cost.

The most important investment is the boat amongst the fix cost. The boat is very multi-uses tools, or it is not exaggerated that the boat is the native's car without it nothing can be done. From the other aspect, whether families living partially on fishing or not, they all own a boat in that a farmer with the orange plantation which is the families' most important asset must need a boat for convenient to sell the orange at the favorable price. As a result of it, the fishing is, loosely speaking, byproduct of plantation. One boat may cost 1 thousand dollars in 2002, but it can be used by at least ten years. The variable cost for the boat, oil, may also be little for fishing location nears home by the limiting of electricity. So the cost about boat for the fishing can be ignored.

Another cost is about the net. To the ice fish, the net's material is plastic fiber which is flexible and elastic, which have wide usefulness in the native daily life. Every square plastic net may cost 0.4 dollar. In 2000, the net was about area: 5 m × 5 m and mesh size: 2—3 mm which cost about 7.5 dollar. In 2005, the area of net became increase to average 10m width × 10m length but the mesh size is same which may cost 30 dollar. Reasons of changes may be apparent that ice fish population decreased so significantly in 2004 that to maintain income unchangingly only has to improve the rate catch effort rate. One plastic net can be used over four years, or it can be fishing over 500 nights, per night use over 5 times. And the net cost of every night may be 0.015 dollar in 2000 and 0.06 dollar in 2005.

For white fish, the net is more expensive for the material is metal. A metal net has narrow alternative usefulness. So if it can not be used as a fishing tool, the net may be wasted. Every square metal net may cost 0.5 dollar. In 2000, a net's width and length may be 10m and 10m expend by 50 dollar. Like the net of ice fish, for the declining density of white fish in 2004, the size became 20m width and 20m length expending by 100 dollar (a discount for significant amount) and since then the size changes little. The life expectation of a net is used 700 nights about 5 years, per night use over 4 times. And the cost of every night in 2000 and 2005 is 0.12 dollar and 0.3 dollar, respectively.

The other fish apparatus is a steel wire, a bulb, a lever. The steel wire can be found in every native families and can be used everywhere. So the cost may be zero. The lever is made by wood operating by human force, no cost.

The only variable cost is the electricity. The bulb is to attract the fish and consumes electricity. A bulb is sufficient and necessary in every fishing apparatus. The bulb for fishing ice fish is commonly 5000W, lights 8 hours per night and costs 4 dollars. The bulb for white fish is 10000W, light 8 hours per night, and cost 8 dollar. Every bulb may cost 100 dollar and can light 100 thousand hours. So the fix cost can be ignored.

We postulate that the cost for ice fish and white fish is per apparatus night 4 dollars and 8 dollars, which is sensible, consequently.

2.5 Catch Effort Rate

The potential capacity of ice fish and white fish may be 1.8 million kg and 9million kg. In 2000 which was the first catching year and in which the catch may be near the potential capacity, catch of ice fish may be per year 600 kg in an apparatus, and the potential may be 600 × 3000, where we accorded the office data that there were 3 thousand apparatuses in fish industry in 2002 which only one fifty was remained in 2010 and the others changed into other industries. But in 2010, per apparatus can only catch per year 20 kg. In 2000, every apparatus of white fish may capture 3000kg. And using the same method, we can infer the potential capacity may be 3000×3000 where according to office record, there were 3 thousand apparatuses in fish industry in 2002 which only few of them or less 0.1% was remained in 2010 and the rest disappeared. But in 2010, we can not observe the apparatus for only white fish. By interview, we know that in 2007, an apparatus for white fish can obtain per night less 2kg averagely. The white fish may be byproduct of ice fish by non-selection fish technology.

The estimation of catch effort rates is subtler than capacity. We assume the identical characteristics amongst the fishers, which may simplify our work. Additional, the ice fish and white fish does not live in groups and roughly distributes uniformly. One site's catch rate around the Lake is the same as the other's rate. Both use the photokinesis (a property that the create likes the light in the night) , by which the constant catch rate can be maintained. By averaging the catch rate within the data from the 7 observations from 2000 to 2004, derive that the catch rate of ice fish was 10^{-5} kg per apparatus day. And after 2004, for adopting net with double scale, the catch rate of ice fish is $2*10^{-5}$ kg per apparatus day. Before 2005, the catch rate of white fish was $2.5*10^{-4}$ and after 2004 was $5*10^{-4}$. We should emphasize that the catch rate may never be precisely estimated in the actuality but the data may be close the real and not be influenced the eventual results.

3. Model Applications

A fishery is though as collapse if the harvest in one year is less that 10% of the maximum recorded harvest up to the year (Costello, Gaines, & Lynhan, 2008). In this part, we combine the first and second sections to examine the theory supposition that government's objective lead to resource collapse. In China, the government's tenure is only four years. In the first period, the sudden intensive resource exploitation is prevailing to obtain the optimal stock as soon as possible. Lacking management can immediately result into resource collapse. In the second period, when government try to management the collapsed resource but immediately find that un-management be optimal choice. So the resource is always collapse and discount rate is exceedingly high.

In the first period, production is high, fish' price is relative low and size of net is relative small, compared with the second period. Firstly, consider the effect of discount rate on resource stock and catch effort, given by table 1

Table 1. Optimal equilibrium solutions before 2004*

θ	social optimal model				office optimal model			
	x^*	y^*	e_x^*	e_y^*	x^0	y^0	e_x^0	e_y^0
0	9.37E+05	4.51E+06	3.84E+04	0	7.36E+04	2.67E+04	7.67E+04	0
1%	9.26E+05	4.29E+06	3.88E+04	0	7.36E+04	2.67E+04	7.67E+04	0
3%	9.06E+05	3.84E+06	3.97E+04	0	7.36E+04	2.67E+04	7.67E+04	0
5%	8.85E+05	3.40E+06	4.07E+04	0	7.36E+04	2.67E+04	7.67E+04	0
10%	8.34E+05	2.29E+06	4.29E+04	0	7.36E+04	2.67E+04	7.67E+04	0
50%	4.63E+05	3.69E+04	5.93E+04	0	7.36E+04	2.67E+04	7.67E+04	0

* The notations in the table are the same as the first and second sections.

From table 1, one noticeable feature is always no direct and special exploitation of the white fish resource in both models. And without any surprise, in ideal optimal model the conservation of resource in limited entry is worked better than the free entry model.

The above analysis reveals exactly the reality. After 5 three years in fully exploitation by 2005, the ice fish and white fish are appropriately reduced into 4% of potential capacity, and 3%, respectively. The both resources are extremely collapsed. Without technology advance, many of fishers must have to be expelled to go off fisher industry in that it can not maintain the initial employment. Compared with social welfare optimal model, the resource stock is less an order in the office optimal model.

The validity may be justified by another interesting fact that after 2004, the government does manage the fisher industry to try to prevent the resource from collapsing. But after only a season in 2005, the government discovered that the management is not necessary because at that time the fishing apparatuses significantly reduce suddenly. As the common sense, the government should take action to avoid rent dissipation to maximize the social well being. But we know that the government actions always have lagged. In the first period, the government should take measures to keep the resource from being over utilized. But if measures should take in the first period but be delayed to carry out until the second period, their effects would have little or no benefits and eventually measures may be abolished for balancing between cost and return.

Although in essence the government' behaviors are rational in that selecting no management is the optimal choice for government income in the secondary period when the resource had been collapsed and no net returns can be produced, when compared with talbe2 we found after the technology advance the effort in 2005 was less 5% of effort in 2004. So in 2005, over 90% fishers were forced to seek other jobs and others tried to improve catch abilities in that the speed of decreasing the fish resource stock was faster that the speed of increasing the high price. In 2005, the ice fish price is about four times than before, and white fish price is two times than before.

So the government had no incentive for managing fishery in that low fish stock can not bring enough revenues to compensating cost. But for the remaining fisher, although in competitive equilibrium ones can averagely earn zero net in long term, one who first heighten catch efficiency can acquire positive net returns. So no one can escape the vicious competition of catch efficiency. The table 2 depicts influence of 2005's improvement.

Table 2. Optimal equilibrium solutions after 2004*

θ	Social optimal model				Office optimal model			
	x^*	y^*	e_x^*	e_y^*	x^0	y^0	e_x^0	e_y^0
0	9.04E+05	4.50E+06	1.99E+04	0	9.20E+03	8.00E+04	3.97E+03	0
1%	8.93E+05	4.28E+06	2.02E+04	0	9.20E+03	8.00E+04	3.97E+03	0
3%	8.71E+05	3.83E+06	2.06E+04	0	9.20E+03	8.00E+04	3.97E+03	0
5%	8.49E+05	3.38E+06	2.11E+04	0	9.20E+03	8.00E+04	3.97E+03	0
10%	7.93E+05	2.26E+06	2.24E+04	0	9.20E+03	8.00E+04	3.97E+03	0
50%	3.57E+05	6.67E+03	3.21E+04	0	9.20E+03	8.00E+04	3.97E+03	0

* The notations in the table are the same as the first and second sections.

Examining the table 2, there solutions are the same except showing reducing scale after 2004 contrasting with before 2004. Apparently, with more rate of discount, the government management loses the economic foundation.

Internal competition mechanism can compel the fishers into the tragedy of common. The office optimal model shows that the resources should be collapsed. But under social optimal model, the resources are not. In the first period, government needs time to remove information obstacle and carefully program. So government's measure is always put forth lately and enforce lately. In the second period, however, if the government's objective is to maximize the social welfare, the resource would also be recovered by simply taking measures to completely ban exploitation. But if banning exploitation in reality, government would certainly expend some cost to enforce there measures and return to nothing. So under self-interesting office, there are not feasible. We call this phenomenon government-led over exploitation, and phenomena of this kind are wide existence in contemporary China.

Government-led over exploitation is the significant feature in developing country where actions of government are lagged seriously and the government's objective is not social welfare maximization but self-office revenue maximization. Of course, the lagging is partially caused by sudden of initial resource exploitation.

4. Extensions

We have adopted comparatively simple models to treat interaction between the fisher objective, government objective and resource conservation. In this section we relax two of our assumptions and argue that our basic results are not sensitive to reasonable departures from them.

4.1 Selective Fishing

It can not be completely selective fishing in the high-technology fishery in the developed country, let alone in the developed country China. But we assume that, instead of the non selective fishing technology, as the technology advance the fishers can precisely distinguish different species and effectively use the fish resource. In first model, the social welfare maximization model, changing equation (3), catch equation can be given and in order to not confuse solutions in the section 1 with this section, superscripts '-*' denote optimal solutions in the first model in this section,

$$h_y = q_y e_y y \, , 0 \le e_y \le e_{\max} \tag{27}$$

And then change the equation (15) and equation (16); get the following conclusions,

$$x^{-*}=\frac{-p_x\theta+\frac{c_x}{q_x}\frac{\gamma_x}{K_x}+p_x\gamma_x+\sqrt{(p_x\theta-\frac{c_x}{q_x}\frac{r_x}{K_x}-p_x\gamma_x)^2+8\frac{p_x\gamma_x\theta}{K_x}+\frac{c_x}{q_x}}}{\frac{4p_x\gamma_x}{K_x}} \tag{28}$$

$$y^{-*}=\frac{-p_y\theta+\frac{c_y\gamma_y}{q_yK_y}+p_y\gamma_y+\sqrt{(p_y\theta-\frac{c_y\gamma_y}{q_yK_y}-p_y\gamma_y)^2+8\frac{p_y\gamma_yc_y\theta}{K_yq_y}}}{\frac{4p_y\gamma_y}{K_y}} \tag{29}$$

$$e_x^{-*}=\frac{\gamma_x(1-\frac{x^*}{K_x})}{q_x} \tag{30}$$

$$e_y^{-*}=\frac{\gamma_y(1-\frac{y^*}{K_y})}{q_y} \tag{31}$$

In the second model, fisher objective equation, we use the selective fishing technology, and get the following inference, superscripts '-o' denote optimal solutions in the second model in this section,

$$x^{-0}=\frac{c_x}{p_xq_x} \tag{32}$$

$$y^{-0}=\frac{c_y}{p_yq_y} \tag{33}$$

$$e^{-0}{}_x=\frac{\gamma_x(1-\frac{c_x}{p_xq_xK_x})}{q_x} \tag{34}$$

$$e^{-0}{}_y=\frac{\gamma_y(1-\frac{c_y}{p_yq_yK_y})}{q_y} \tag{35}$$

Use the same procedure as the section 3, from table 3, we examine that conclusions are valid that the government's lagged actions lead to resources seriously collapsed in the first period and in the second period government's optimal choice maybe let resources free entry if government's objective is office welfare maximization. We show that the social welfare optimal model and office welfare optimal model obtain the roughly same resource conservation level for 50% discount rate, additionally.

Table 3. Optimal equilibrium solutions before 2004*

θ	Social optimal model				Office optimal model			
	x	y	e_x	e_y	x	y_-	e_x	e_y
0	9.40E+05	4.51E+06	3.82E+04	3.98E+02	80000	26700	76400	798
1%	9.29E+05	4.29E+06	3.86E+04	4.19E+02	80000	26700	76400	798
3%	9.09E+05	3.84E+06	3.96E+04	4.58E+02	80000	26700	76400	798
5%	8.89E+05	3.40E+06	4.05E+04	4.98E+02	80000	26700	76400	798
10%	8.38E+05	2.29E+06	4.27E+04	5.96E+02	80000	26700	76400	798
50%	4.72E+05	3.69E+04	5.90E+04	7.97E+02	80000	26700	76400	798

* The notations in the table are defined in section 3.

The argument is also efficient in table 4 which simulates the outcome after 2004 by the data from the section 3.

So we conclude that if the resource can be well defined and nice managed and even if it can not reach the social Pareto optimality, the resource can be sub-optimality; it never happen that well management system and lawless system can bring the same outcomes. Unfortunately, the reality works out non-management path.

Table 4. Optimal equilibrium solutions after 2004*

θ	Social optimal model				Office optimal model			
	$\bar{x}^*$	$\bar{y}^*$	$\bar{e}_x^*$	$\bar{e}_y^*$	$\bar{x}^0$	$\bar{y}^0$	$\bar{e}_x^0$	$\bar{e}_y^0$
0	9.05E+05	4.50E+06	1.99E+04	1.99E+02	10000	8000	39800	396
1%	8.93E+05	4.28E+06	2.01E+04	2.10E+02	10000	8000	39800	396
3%	8.71E+05	3.83E+06	2.06E+04	2.30E+02	10000	8000	39800	396
5%	8.49E+05	3.38E+06	2.11E+04	2.50E+02	10000	8000	39800	396
10%	7.93E+05	2.26E+06	2.23E+04	3.00E+02	10000	8000	39800	396
50%	3.18E+05	6.67E+03	3.20E+04	4.00E+02	10000	8000	39800	396

* The notations in the table are defined in section 3.

4.2 Fine Index

We assume that the fine index is constant, an exogenous variable. It is convenient to assume that the index is related with the government cost. And we assume that if more cost used to manage fish resource then higher percent of fishers' revenue flow may be plundered. Then the government net revenue may be $\mu(c(t))R(t)-c(t)$. Analyzing this expression, we recognize that $\mu'(c(t))c'(t)R(t)+\mu(c(t))R'(t)>\mu(c(t))R'(t)$, so the government would be earlier to retrain from resource when the fine index is variable rather than constant, if cost function is concave. And if cost function is a convex function, the government would manage the fishery longer time when the fine index is variable than when the fine index is constant. The fisher' optimal solutions have not relation with the fine index. Consequently, changing the index may not influence fishers' optimal choice. Obviously, when the net revenue for the fishers is zero in the second period, whatever value the fine index is, the optimal selection for the government maybe no longer spend any cost in fishery management. It does not alter the outcome of office welfare maximization model. For the social welfare optimal model, the fine index can exert non influence.

5. Conclusion

This purpose of this paper was to develop a simple theory in which lagged actions of government and office welfare maximization lead to resource collapse, to help us understand the wide phenomena that resources which are over exploitation in developing country are apparently economically rational, in essence. The theoretical literature often has exclusively focused on a fixed frame in which the resource is already collapsed and ignores the initial exploitation stage. Additionally, the literature often assumes the government's objective for social welfare maximization but in reality it is not.

Government emphasizing short and self-interest focus is much more apparently in developing country, like China, where the social democratic procedure has not been nicely executed. Many resources are commonly owned and every one has the right to exploitation without any restriction. But it is only the apparent view, and the phenomena can not give a convincible reason why it is not existence of government interference.

By dividing the fishing period into two stages, the initial period in which fish population decease from the full capacity to a low stock level at the most rapid catch speed, and the second period in which fish stock is stable decrease at relative low speed in the longer time. In the first period, the government takes no action to manage the fishery in that there is information asymmetrical gap between government and fishers. And government needs time to gather the necessary information for decision. In the secondary period, government chooses no management again in that there is no net revenue in the second period. For fishers, the only choice is to catch fish as much as possible in the shortest time in that there is high discount rate and so little investment in a apparatus that every one can afford the cost of access to fishery. Solutions are the sub-game perfect Nash equilibrium.

For justifying the argument, we use Dong Jiang Lake as an example and investigate the Gaopu village in detail. By comparing with reality and simulation outcomes, we conclude that the above argument is convincing. By relax the non selective assumption and fix the fine index, the conclusions can also be robust.

Out simple theory not only applies to exploitation process for renewable resource, like fish resource but also the non-renewable resource, like the mine. Exploitation of the gold mine is the typical example. In the first period, there is a gold rush under no management. After the first period, the resource has been largely exploited. And then the government enforces measures to forbid disorderly development. But no body, even the government, could be sure that the measures can be effective implementation, let alone the prospectors. This was really happened in 19 century in American. In out model, we do not consider the individual difference amongst fishers. This is an interesting aspect in that different individual may choose the divergent selection. The stochastic factor is another feature of fishery. And the sample may be too small. So there is much scope for further research along this line.

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