Fishery Subsidies: Gains or Losses?

Pat Pattanarangsun

Ph.D. Candidate

School of Development Economics
National Institute of Development Administration
Serithai Road, Klong-Chan, Bangkapi
Bangkok, Thailand 10240.

Abstract

This paper investigates the impacts of fishery subsidies by looking at total welfare losses or gains from the demand and supply diagram. The additional idea is to combine environmental problems and introduce the term "externality cost" into the analysis. The kinked marginal externality cost is a key factor helping subsidy programs to be beneficial. Two types of subsidies are considered in this study: export and effort subsidies. However each type of subsidy has been subdivided into three cases with different scenarios of an optimal fishing amount. The results show that if the current level of fishing already exceeds the optimal level, fishery subsidies should not exist. But if this is not the case, the conclusion is ambiguous depending on the rate of the subsidy and the degrees of externality problems. At the end of this paper, I summarize the study results for all scenarios in six models and propose a way to examine the optimal subsidy rate for further analysis.

Keywords: Fishery subsidies, Taxes and subsidies, Trade and environment

JEL classification: F13, F18, H23, Q22, Q28

1. Introduction

In modern times, the development of the fishery sector has gained intense international attention, particularly focusing on the environmental impact of excessive fishing. The issue of fishery subsidies has been debated internationally given the concern that they directly result in increasing fishing capacity and over-fishing. The threat of over-fishing has put long-time opponents in the same "boat" as free-trader advocates and environmentalists push to use the World Trade Organization (WTO) to end subsidies that encourage depletion of global fish stocks. The ban on subsidies is being promoted by several countries, calling themselves the "Friends of Fish" and eleven other environmental groups, including the World Wide Fund for Nature and Greenpeace, as part of the overall Doha trade round.

It is well-established in microeconomics that subsidies, in general, reduce total welfare. Even though they increase a surplus in one sector, they may lower surplus in the others and the government also loses money. For example, in the case of export subsidies, the consumer surplus will be lower due to the higher price of goods and less consumption, but the producer surplus will be higher from greater profit. However, the government payment will cause the total welfare to decrease. It seems that subsidies are not a good policy instrument, especially for fisheries, which may lead to over-fishing problems; additionally, decreased fishing may also negatively impact trade and the environment. On the trade side, welfare will be low due to the small amount of consumption and production. On the environment side, it can create too great a stock of fish in the sea, thus leading to lower growth and inefficient catching. Given these impacts, it is not clear whether there will be net social gains or losses from fishery subsidies. It depends on the nature and size of the environmental externality cost or benefit associated with trade. A lot of studies have been carried out on fishery subsidies. Most of them considered the positive and negative impacts, using case studies and qualitative modeling. Danilo C. Israel and Cesar P. Banzon (2002), for example, studied subsidies in the Philippines and found an over-fishing problem. They then recommended canceling the subsidy programs in the Philippines[1]. Nobuyuki (2002) argued that fishery subsidies may not cause unwelcome externalities, such as over-fishing and trade distortion, if good fishery management is involved and he found that fishery production would been more directly affected by resource management and market conditions than by the number of subsidies. Anne Tallontire (2004) confirms this argument by proposing that the removal of subsidies alone will not solve the problem of over-fishing; an effective fishery management system is a more important factor.

Due to the many arguments above, this paper will examine this issue from another approach by constructing a simple model and explaining social welfare using demand-supply diagrams with a focus on externalities.

2. Theoretical Frameworks

2.1 Impacts of subsidies on the domestic market

Consider a competitive market with inverse demand function: P = f(x) and supply function: MC = g(x)

Let	P	=	price of fishery goods
	P_w	=	world price
	MC	=	marginal cost
	x	=	number of fishery goods
	c_0	=	amount of consumption
	x_0	=	amount of production

In free trade, the market will face a kinked demand curve (D), as shown in Figure 1. Price is equaled to world price (P_w). The production and consumption levels are x_0 and c_0, respectively. Therefore the gap $x_0 - c_0$ is the export amount.

[1] Philippines is one of 11 countries in "friends of fish" group who calls for banning fishery subsidies.

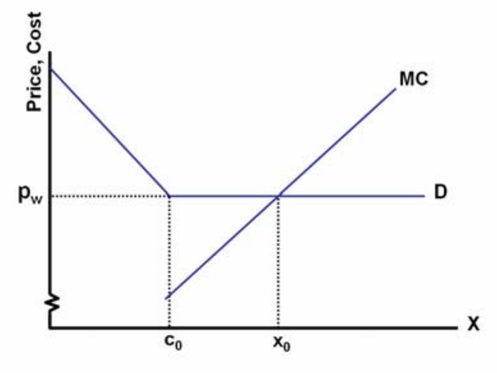

Figure 1: Domestic export market

2.2 Optimum Use of Fishery Resources

In this paper, I selected the concept of Maximum Sustainable Yield (MSY) to be the optimum fish catch (k). The aim is to avoid over-fishing of the stock but at the same time to allow the maximum catch to be removed. (See Figure 2).

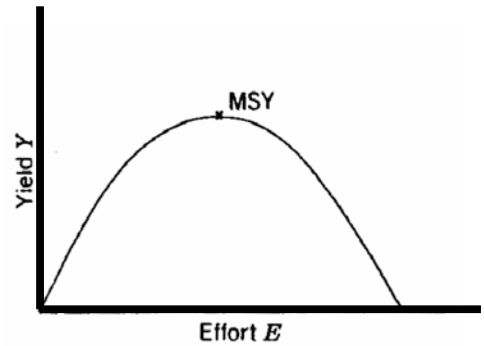

Figure 2: The sustainable yield-effort curve (from Schaefer, 1954)

2.3 Marginal Externality Cost

Let MEC = Marginal Externality Cost
MPC = Marginal Private Cost
MSC = Marginal Social Cost

When considering externality or introducing the MEC, the MSC will be the sum of the MEC and the MPC. In the case of fisheries, it is assumed that too much or too little fish stock can lead to negative externality problems and that there is no additional externality cost at x* (MSY). This leads to a kinked MEC curve with an asymmetric pattern ($\theta_1 > \theta_2$), as shown in Figure 3.

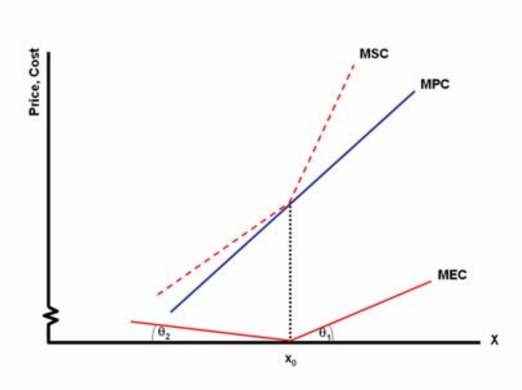

Figure 3: Externality cost

3. Models and Diagrams

Assume linear demand and supply function as follows:

(1) $P = a - bx$ (Inverse demand function)

(2) $MC = c + dx$ (Supply function, which is MPC or MC)

where a, b, c and d are all positive.

The domestic demand function in free trade is

(3) $$P = \begin{cases} a - bx & ; x < (a - p^*)/b \\ p^* & ; x \geq (a - p^*)/b \end{cases}$$

The MEC is assumed to be linear and can be written as

(4) $$MEC = \begin{cases} \gamma_1(x - k) & ; x > k \\ \gamma_2(k - x) & ; x \leq k \end{cases}$$

where γ_1 and γ_2 represent the degrees of externality problems from too much and too few fish catches, respectively[2]

and k is the optimal fish catch given by MSY in natural resource economic problem (at this level, MEC = 0)

Consider (2) and (4), the MSC function is:

(5) $$MSC = \begin{cases} (c - \gamma_1 k) + (d + \gamma_1)x & ; x > k \\ (c + \gamma_2 k) + (d - \gamma_2)x & ; x \leq k \end{cases}$$

The market partial equilibrium[3] can be determined as follows:

i) Without externality concern

Consider (2) and (3), the equilibrium is (x_0, p^*)

(6) $x_0 = (p^* - c)/d$

---

[2] γ_1 is expected to be greater than γ_2 because the negative impact of too much fishing or scarce fish stock seems to be greater than on a too small fishing or dense fish stock. (I mean higher fish catch,less fish stock

[3] I assumed the equilibrium is located on the horizontal part of the demand curve, $P = p^*$. (I mean P=p* is demand equation)

ii) With externality concern

Consider (3) and (5), the social equilibrium is (x_{0s}, p^*)

(7) $x_{0s} = \begin{cases} (p^* - c + \gamma_1 k)/(d + \gamma_1) & ; x > k \\ (p^* - c - \gamma_2 k)/(d - \gamma_2) & ; x \le k \end{cases}$

The effects of fishery subsidies on supply and demand function are different according to the type of subsidies. In this paper, I discussed and compared two methods of fishery subsidies: Export Subsidies and Fishing Effort Subsidies.

3.1 Export Subsidies

This type of subsidy can be achieved by increasing fishery prices to motivate exports. Supposing that the subsidy rate per unit is s, the domestic demand will change from D to D' as illustrated in Figure 4.

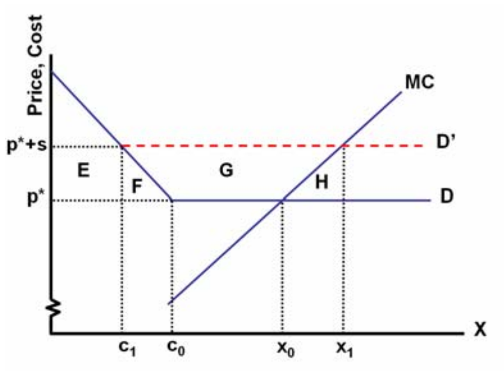

Figure 4: Domestic market in free trade with export subsidies

Figure 4 shows the changes in welfare: consumer surplus, producer surplus and cost of government subsidies. With subsidies, the price p* grows to p*+ s. This leads to consumer loss in the amount of E + F and producer gain in the amount of E + F. The government pays in the amount of F + G + H; therefore, the net welfare loss is F + H.[4]

The new domestic export demand function after the subsidy can now be written as:

(8) $P = \begin{cases} a - bx & ; x < (a - p^* - s)/b \\ p^*+s & ; x \ge (a - p^* - s)/b \end{cases}$

Consider (2) and (8), the equilibrium is (x_1, p^*+s)

(9) $x_1 = (p^* + s - c)/d$

The Initial welfare loss[5] , which is equal to area F + H, can be given by

(10) Initial welfare loss = $(s^2/2)[(1/b)+(1/d)]$

[4] Consider a case of small country, so the world price does not change. If this is not the case, total welfare loss will be larger.

[5] According to the slopes of demand and supply curves which are -b and d, respectively, the change in consumption $(c_0 - c_1)$ and production $(x_1 - x_0)$ can be easily determined as s/d and s/b, respectively.

Equation (10) confirms that the subsidy reduces welfare although it can increase producer surplus but is not enough to compensate with less consumer surplus and government cost. But this paper will introduce the term externality cost into the model and diagram. As I mentioned above that too much and too little fishing comparing to an optimal level (k) lead to externality but in different degrees[6]. The indifference in all cases is that the welfare will be reduced when the model concerns externality problem. Comparing with and without subsidies, it is ambiguous to conclude that which one makes a bigger welfare loss. It depends on the k value, in the other word what the position of fishing today with and without subsidies (x_0 and x_1) is. Therefore I subdivided the models in the case of export subsidies into 3 cases:

Case1: $k<x_0<x_1$

It is the case that the too much fishing occurs at the beginning before subsidization. (See Figure 5).

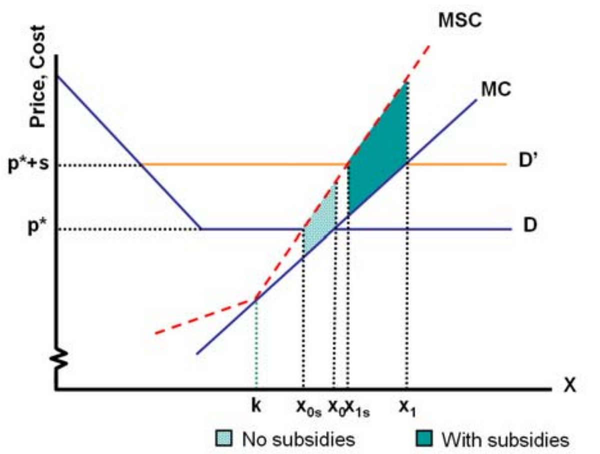

Figure 5: Welfare loss with externality concern for export subsidy - case1

In this case the equilibrium with externality concern will be determined by using the MSC in the steeper part (degree γ_1) for both with and without subsidies.
i.e. $MSC = (c - \gamma_1 k) + (d + \gamma_1)x$

Consider (7), the social equilibrium without export subsidies is (x_{0s}, p*)
$x_{0s} \;=\; (p^* - c + \gamma_1 k)/(d + \gamma_1)$

Consider (5) and (8), the social equilibrium with export subsidies is (x_{1s}, p*+s)
$x_{1s} \;=\; (p^* + s - c + \gamma_1 k)/(d + \gamma_1)$
Consider Figure 5, the welfare loss when introducing externality in the case of no subsidy is the shaded area[7] on the left hand side, which is equal to:

$$\frac{1}{2}\left[\frac{p^*-c}{d}-\frac{p^*-c+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[p^*-c-\frac{d(p^*-c+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[(c-\gamma_1 k)+\frac{(d+\gamma_1)(p^*-c)}{d}-p^*\right]$$

Let $\Delta\omega_0$ = the welfare loss when introducing externality in case of no subsidy
$A = p^* - c$

[6] It depends on γ_1 and γ_2, which are the marginal MEC in the case of too much and too little fishing, respectively.
[7] Area of Trapezoid is height * (base1 + base2) / 2

(11) $$\Delta\omega_0 = \frac{1}{2}\cdot\frac{\gamma_1^3(A-dk)^3}{d^2(d+\gamma_1)^2}$$

Proof. See Appendix A

Consider Figure 5, the welfare loss when introducing externality in the case of with subsidy is the shaded area on the right hand side, which is equal to

$$\frac{1}{2}\left[\frac{p^*+s-c}{d}-\frac{p^*+s-c+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[p^*+s-c-\frac{d(p^*+s-c+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[(c-\gamma_1 k)+\frac{(d+\gamma_1)(p^*+s-c)}{d}-p^*-s\right]$$

Let $\Delta\omega_1$ = the welfare loss when introducing externality in the case of with subsidy

$B = p^* + s - c$

(12) $$\Delta\omega_1 = \frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2}$$

Figure 5 tells us that when an export subsidy is used, it increases welfare loss (larger area). Consider (11) and (12), welfare loss rises in the amount of $\Delta\omega_1 - \Delta\omega_0$

(13) $$\Delta\omega_1 - \Delta\omega_0 = \frac{\gamma_1^3}{2d^2(d+\gamma_1)^2}\cdot(s)\cdot\left\{3\left[(dk-p^*+c)^2+2dkc+s(p^*-c)\right]+s^2\right\}$$

Proof. See Appendix B

Consider (13), the total term is always positive. This is because the too much fishing occurs at the beginning before subsidization. Thus introducing subsidies leads to more fishing and higher externality costs. The welfare loss then always increases.

Case2: $x_0<k<x_1$

It is the case that the too much fishing does not occur at the beginning but that problems appear after subsidization. (See Figure 6).

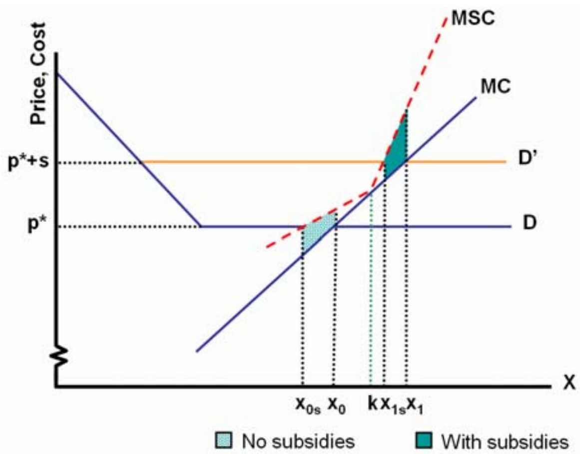

Figure 6: Welfare loss with externality concern for export subsidy – case2

In this case the equilibrium with externality concern will be determined by using the MSC in the flatter part (degree γ_2) for the case without subsidies,

i.e. MSC = $(c + \gamma_2 k) + (d - \gamma_2)x$
and in the steeper part (degree γ_1) for the case with subsidies,
i.e. MSC = $(c - \gamma_1 k) + (d + \gamma_1)x$

Consider (7), the social equilibrium without export subsidies is (x_{0s}, p^*)

$x_{0s} \quad = \quad (p^* - c - \gamma_2 k)/(d - \gamma_2)$

Consider (5) and (8), the social equilibrium with export subsidies is (x_{1s}, p^*+s)

$x_{1s} \quad = \quad (p^* + s - c + \gamma_1 k)/(d + \gamma_1)$

Consider Figure 6, the welfare loss when introducing externality in the case of no subsidy is the shaded area on the left hand side, which is equal to

$$\frac{1}{2}\left[\frac{p^*-c}{d}-\frac{p^*-c-\gamma_2 k}{d-\gamma_2}\right]\cdot\left[p^*-c-\frac{d(p^*-c-\gamma_2 k)}{d-\gamma_2}\right]\cdot\left[(c+\gamma_2 k)+\frac{(d-\gamma_2)(p^*-c)}{d}-p^*\right]$$

$$(14) \quad \Delta\omega_0 = \frac{1}{2}\cdot\frac{\gamma_2^3(dk-A)^3}{d^2(d-\gamma_2)^2}$$

Consider Figure 6, the welfare loss when introducing externality in the case of with subsidy is the shaded area on the right hand side, which is equal to

$$\frac{1}{2}\left[\frac{p^*+s-c}{d}-\frac{p^*+s-c+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[p^*+s-c-\frac{d(p^*+s-c+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[(c-\gamma_1 k)+\frac{(d+\gamma_1)(p^*+s-c)}{d}-p^*-s\right]$$

$$(15) \quad \Delta\omega_1 = \frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2}$$

Figure 6 tells us that when an export subsidy is used, it is not possible to conclude whether the welfare loss increases or decreases. Consider (14) and (15), welfare loss rises in the amount of $\Delta\omega_1 - \Delta\omega_0$

$$(16) \quad \Delta\omega_1 - \Delta\omega_0 = \frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2} - \frac{1}{2}\cdot\frac{\gamma_2^3(dk-A)^3}{d^2(d-\gamma_2)^2}$$

Consider (16), the total term may be positive or negative depending on the parameters, especially k, γ_1 and γ_2. A higher k value implies less welfare loss when introducing a subsidy because the fishing level will be nearer the optimal point. A big difference between γ_1 and γ_2 ($\gamma_1 > \gamma_2$) tends to increase welfare loss when introducing a subsidy because it implies that we are serious for too much than too little fishing .

Case3: $k< x_0<x_1$

It is the case that too little fishing occurs even though the subsidy program exists.
(See Figure 7).

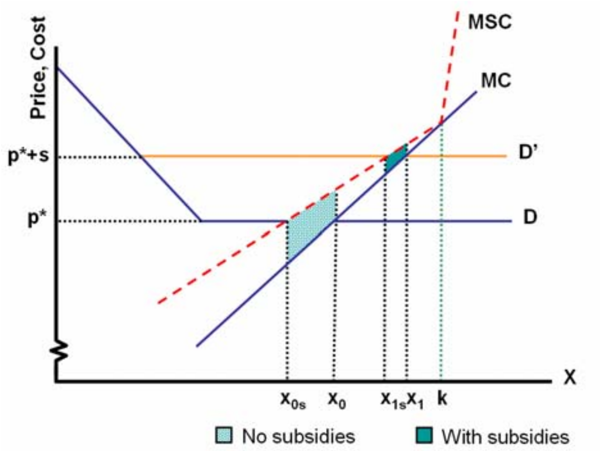

Figure 7: Welfare loss with externality concern for export subsidy – case3

In this case the equilibrium with externality concern will be determined by using MSC in the flatter part (degree γ_2) for both with and without subsidies,
i.e. MSC = $(c + \gamma_2 k) + (d - \gamma_2)x$

Consider (7), the social equilibrium without export subsidies is (x_{0s}, p*)

$x_{0s} \quad = \quad (p^* - c - \gamma_2 k)/(d - \gamma_2)$

Consider (5) and (8), the social equilibrium with export subsidies is (x_{1s}, p*+s)

$x_{1s} \quad = \quad (p^* + s - c - \gamma_2 k)/(d - \gamma_2)$

Consider Figure 7, the welfare loss when introducing externality in the case of no subsidy is the shaded area on the left hand side, which is equal to:

$$\frac{1}{2}\left[\frac{p^*-c}{d}-\frac{p^*-c-\gamma_2 k}{d-\gamma_2}\right]\cdot\left[p^*-c-\frac{d(p^*-c-\gamma_2 k)}{d-\gamma_2}\right]\cdot\left[(c+\gamma_2 k)+\frac{(d-\gamma_2)(p^*-c)}{d}-p^*\right]$$

$$(17) \qquad \Delta\omega_0 = \frac{1}{2}\cdot\frac{\gamma_2^3(dk-A)^3}{d^2(d-\gamma_2)^2}$$

Consider Figure 7, the welfare loss when introducing externality in the case of with subsidy is the shaded area on the right hand side which is equal to:

$$\frac{1}{2}\left[\frac{p^*+s-c}{d}-\frac{p^*+s-c-\gamma_2 k}{d-\gamma_2}\right]\cdot\left[p^*+s-c-\frac{d(p^*+s-c-\gamma_2 k)}{d-\gamma_2}\right]\cdot\left[(c+\gamma_2 k)+\frac{(d-\gamma_2)(p^*+s-c)}{d}-p^*-s\right]$$

$$(18) \qquad \Delta\omega_1 = \frac{1}{2}\cdot\frac{\gamma_2^3(dk-B)^3}{d^2(d-\gamma_2)^2}$$

Figure 7 tells us that when an export subsidy is used, it decreases welfare loss (smaller area). Consider (17) and (18), welfare loss increases in the amount of $\Delta\omega_1 - \Delta\omega_0$ (or decreases in the amount of $\Delta\omega_0 - \Delta\omega_1$).

$$(19) \qquad \Delta\omega_1 - \Delta\omega_0 = \frac{\gamma_2^3}{2d^2(d-\gamma_2)^2}\cdot(-s)\cdot\left\{3\left[(dk-p^*+c)^2+2dkc+s(p^*-c)\right]+s^2\right\}$$

Consider (19), the total term is always negative. This is because too little fishing occurs even with subsidization. Thus, introducing subsidies leads to more fishing and the fishing level moves toward k value. The welfare loss then will always decrease.[8]

In order to examine the total welfare gain or loss from export subsidies, I combined the initial welfare loss (from (10)) and welfare loss/gain from externality concern (from (13), (16) and (19)). The first case confirms the welfare loss from the export subsidy, while the other two cases are too ambiguous to make a conclusion?.

3.2 Effort Subsidy

This type of subsidy can be done by decreasing input price. Suppose the subsidy rate per unit is s; the supply curve or marginal cost will change from MC to MC', as illustrated in Figure 8.

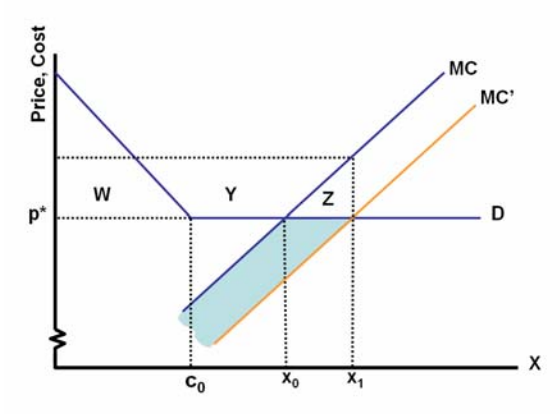

Figure 8: Domestic market in free trade with effort subsidies

Figure 8 shows the changes in welfare: consumer surplus, producer surplus and cost of government subsidy. With subsidies, the price p* and consumption c_0 do not change but the fishing increases from x_0 to x_1. This leads to producer gain in the amount of the shaded area, while consumer surplus is constant. The government pays money in the amount of W + Y + Z, which is equal to the sum of the shaded area and Z; hence, the net welfare loss is area Z.

The new supply function after the subsidy is now able to be written as:

(20) $MC' = c - s + dx$

Consider (3) and (20), the equilibrium is (x_1, p^*+s) [9]

(21) $x_1 = (p^* + s - c)/d$

The Initial welfare loss, which is equal to area Z, can be given by

(22) Initial welfare loss = $s^2/2d$

Equation (22) confirms that the subsidy reduces welfare, although it can increase producer surplus, not enough however to compensate for the government cost. Just as in

[8] In this case, we will gain from the subsidy program because the welfare loss is lower.

[9] It is the same x_1 but at a lower price compared to the case of an export subsidy.

the case of the export subsidy, I have introduced the term externality cost into the models and diagrams. Again, I subdivided the models in the case of effort subsidies into 3 cases:

Case1: $k<x_0<x_1$
It is the case that too much fishing occurs at the beginning before subsidization. (See Figure 9).

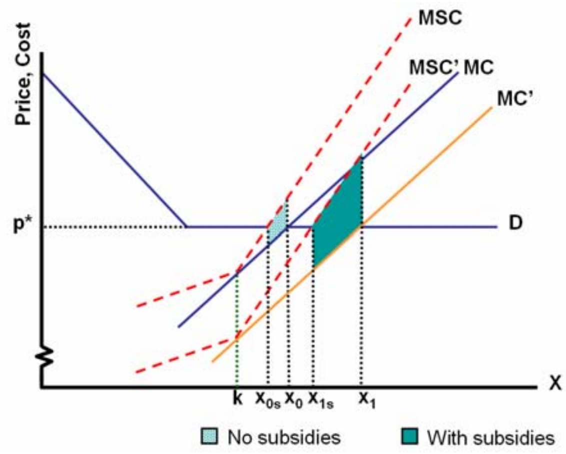

Figure 9: Welfare loss with externality concern for effort subsidy – case1

Comparing Figure 9 to Figure 5, we can see that x_o, x_1, x_{0s}, and x_{1s} will be the same, while the optimal prices after subsidies are different (p* and p*+s for effort and export subsidies, respectively). This is because instead of shifting up the price or D, the MC and MSC shifts down in the same amount: s. This implies that the welfare losses from externality concern are also the same.

Hence $x_{0s} = (p^* - c + \gamma_1 k)/(d + \gamma_1)$

$x_{1s} = (p^* + s - c + \gamma_1 k)/(d + \gamma_1)$

(23) $$\Delta\omega_1 - \Delta\omega_0 = \frac{\gamma_1^3}{2d^2(d+\gamma_1)^2} \cdot (s) \cdot \left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

Consider (23), the total term is always positive. The welfare loss always increases (as with the case of an export subsidy).

Case2: $x_0<k<x_1$
It is the case that too much fishing does not occur at the beginning but that a problem appears after subsidization. (See Figure 10)

$x_{0s} = (p^* - c - \gamma_2 k)/(d - \gamma_2)$

$x_{1s} = (p^* + s - c + \gamma_1 k)/(d + \gamma_1)$

(24) $$\Delta\omega_1 - \Delta\omega_0 = \frac{1}{2} \cdot \frac{\gamma_1^3 (B - dk)^3}{d^2(d+\gamma_1)^2} - \frac{1}{2} \cdot \frac{\gamma_2^3 (dk - A)^3}{d^2(d-\gamma_2)^2}$$

Consider (24), the total term may be positive or negative depending on the parameters, especially k, γ_1 and γ_2. The result is ambiguous.

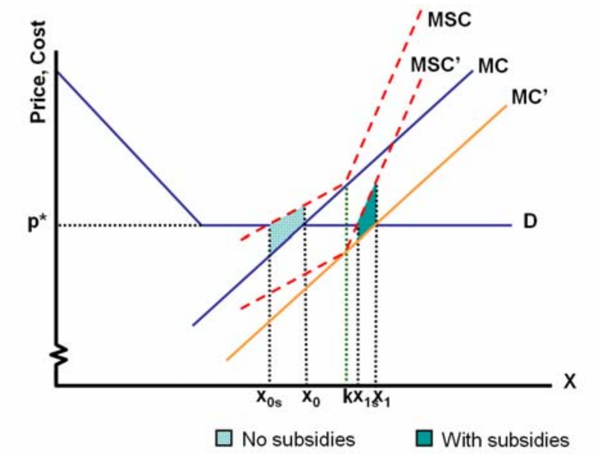

Figure 10: Welfare loss with externality concern for effort subsidy – case2

Case3: $k< x_0<x_1$

It is the case that too little fishing occurs even though the subsidy is used.
(See Figure 11)

$x_{0s} = (p^* - c - \gamma_2 k)/(d - \gamma_2)$

$x_{1s} = (p^* + s - c - \gamma_2 k)/(d - \gamma_2)$

(25) $$\Delta\omega_1 - \Delta\omega_0 = \frac{\gamma_2^3}{2d^2(d-\gamma_2)^2}\cdot(-s)\cdot\left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

Consider (25), the total term is always negative. The welfare loss always decreases (as with the case of an export subsidy).

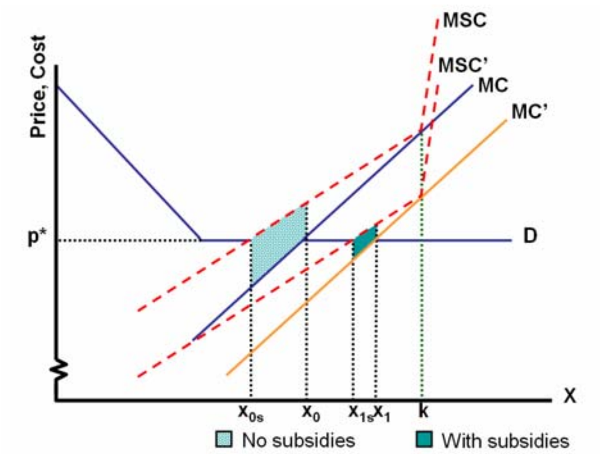

Figure 11: Welfare loss with externality concern for effort subsidy – case3

In order to examine the total welfare gain or loss from an effort subsidy, I combined the initial welfare loss (from (10)) and welfare loss/gain from externality concern (from (13), (16) and (19)), as with the case of the export subsidy. The first case still confirms the welfare loss from the export subsidy, while the other two cases are too ambiguous to make a conclusion about.

It can be seen that with either export or effort subsidies, the welfare loss/gain when considering externality ($\Delta\omega_1 - \Delta\omega_0$) will be the same in each case. The difference is the initial welfare losses, which are $(s^2/2)[(1/b)+(1/d)]$ and $s^2/2$ for export and effort subsidies, respectively. Therefore the models can be set up in the following way:

(26) Net Welfare loss (W) = initial welfare loss + ($\Delta\omega_1 - \Delta\omega_0$)

There will be six models classified by type of subsidy and optimal k value

Model 1: Export subsidy and $k<x_0<x_1$

$$W = (s^2/2)[(1/b)+(1/d)] + \frac{\gamma_1^3}{2d^2(d+\gamma_1)^2}\cdot(s)\cdot\left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

Model 2: Export subsidy and $x_0< k <x_1$

$$W = (s^2/2)[(1/b)+(1/d)] + \frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2} - \frac{1}{2}\cdot\frac{\gamma_2^3(dk-A)^3}{d^2(d-\gamma_2)^2}$$

Model 3: Export subsidy and $x_0<x_1< k$

$$W = (s^2/2)[(1/b)+(1/d)] + \frac{\gamma_2^3}{2d^2(d-\gamma_2)^2}\cdot(-s)\cdot\left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

Model 4: Effort subsidy and $k<x_0<x_1$

$$W = (s^2/2) + \frac{\gamma_1^3}{2d^2(d+\gamma_1)^2}\cdot(s)\cdot\left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

Model 5: Effort subsidy and $x_0< k <x_1$

$$W = (s^2/2) + \frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2} - \frac{1}{2}\cdot\frac{\gamma_2^3(dk-A)^3}{d^2(d-\gamma_2)^2}$$

Model 6: Effort subsidy and $x_0<x_1< k$

$$W = (s^2/2) + \frac{\gamma_2^3}{2d^2(d-\gamma_2)^2}\cdot(-s)\cdot\left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^* - c)\right] + s^2\right\}$$

4. Summary and Extension

In general, subsidies seem to be bad in two main ways. First, they reduce total welfare. Second, they lead to over-fishing problems. This paper introduces externality cost into the analysis by a kinked MEC curve and emphasizes two types of fishery subsidies: export and effort subsidies. The study shows that the same results are the optimal fishing amount and the change of welfare loss when externality is concerned. But the differences are to be found in the price after subsidization and the initial welfare loss, which is higher for the export subsidies. Therefore the effort subsidies seem to be better than the other because they lead to the less total welfare loss. Moreover the effort subsidy can be given by training personnel and improving technology for a better catching method to motivate fishing. In this case the MC may be shift downward more than the amount of subsidies per unit; s, thus there may be a gain from the producer surplus left.

The Net Welfare loss (W) in this paper then is composed of two parts: initial welfare loss and the loss of welfare when externality is concerned ($\Delta\omega_1 - \Delta\omega_0$). The important factors that can affect W are γ_1, γ_2 and k. The parameters γ_1, γ_2 represent the amount of externality problems. The results show that the big difference between γ_1 and γ_2 ($\gamma_1 > \gamma_2$) leads to an increase of welfare loss when introducing the subsidy because it implies that the problem of too much fishing is much more serious than of too little. The other factor is k or optimal fishing. The much higher k compared to the current fishing level leads to a decrease in welfare loss when introducing the subsidy because the fishing level will move closer to optimal point k.

The extension of this study is to apply the models to find optimal subsidy rate (s*) by minimization net welfare loss (W). The problem is to minimize W(s; k, γ_1, γ_2, a, b, c, d)
where s is choice variable
k is the optimal value solved from the natural resource economic problem
γ_1, γ_2 are given by the analyst
a, b, c, d are the coefficients of demand and supply function we have to estimate

For models 1 and 4, which are the cases of $k<x_0<x_1$ or when too much fishing occurs at the beginning before subsidization, W is always positive or the total welfare loss occurs for all values of the subsidy rates. In order to minimize W, we then choose s* = 0 to obtain zero welfare loss. This is reasonable because more subsidies will lead to more fishing and higher externality costs. But in the other models (2, 3, 5 and 6), W may be either positive or negative, depending on other parameters and subsidy rates. Therefore we have to solve for the optimization problem to obtain s*, as mentioned before.

In conclusion, the externality cost should be concerned with both too little and too much fish stock. Moreover, the current level of fishing has to be examined and compared with optimal fishing (k) to measure the impacts and welfare loss from fishery subsidies. Then we can make decisions appropriately because if we ignore externality in the model even though we know the problem, the fishery subsidy will tend to create welfare loss anyway.

Appendix A

Proof that

$$\frac{1}{2}\left[\frac{p^*-c}{d}-\frac{p^*-c+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[p^*-c-\frac{d(p^*-c+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[(c-\gamma_1 k)+\frac{(d+\gamma_1)(p^*-c)}{d}-p^*\right]$$

$$=\frac{1}{2}\cdot\frac{\gamma_1^3(A-dk)^3}{d^2(d+\gamma_1)^2}$$

As we let A = p* – c

$$\frac{1}{2}\left[\frac{p*-c}{d}-\frac{p*-c+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[p*-c-\frac{d(p*-c+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[(c-\gamma_1 k)+\frac{(d+\gamma_1)(p*-c)}{d}-p*\right]$$

$$=\frac{1}{2}\left[\frac{A}{d}-\frac{A+\gamma_1 k}{d+\gamma_1}\right]\cdot\left[A-\frac{d(A+\gamma_1 k)}{d+\gamma_1}\right]\cdot\left[-\gamma_1 k+\frac{(d+\gamma_1)(A)}{d}-A\right]$$

$$=\frac{1}{2}\left[\frac{Ad+A\gamma_1-Ad-d\gamma_1 k}{d(d+\gamma_1)}\right]\cdot\left[\frac{Ad+A\gamma_1-Ad-d\gamma_1 k}{(d+\gamma_1)}\right]\cdot\left[\frac{-d\gamma_1 k+dA+A\gamma_1-Ad}{d}\right]$$

$$=\frac{1}{2}\left[\frac{A\gamma_1-d\gamma_1 k}{d(d+\gamma_1)}\right]\cdot\left[\frac{A\gamma_1-d\gamma_1 k}{(d+\gamma_1)}\right]\cdot\left[\frac{A\gamma_1-d\gamma_1 k}{d}\right]$$

$$=\frac{1}{2}\left[\frac{\gamma_1(A-dk)}{d(d+\gamma_1)}\right]\cdot\left[\frac{\gamma_1(A-dk)}{(d+\gamma_1)}\right]\cdot\left[\frac{\gamma_1(A-dk)}{d}\right]$$

$$=\frac{1}{2}\cdot\frac{\gamma_1^3(A-dk)^3}{d^2(d+\gamma_1)^2}$$

Appendix B

Proof that

$$\Delta\omega_1-\Delta\omega_0=\frac{\gamma_1^3}{2d^2(d+\gamma_1)^2}\cdot(s)\cdot\left\{3\left[(dk-p*+c)^2+2dkc+s(p*-c)\right]+s^2\right\}$$

From (11) and (12)

$$\Delta\omega_1-\Delta\omega_0=\frac{1}{2}\cdot\frac{\gamma_1^3(B-dk)^3}{d^2(d+\gamma_1)^2}-\frac{1}{2}\cdot\frac{\gamma_1^3(A-dk)^3}{d^2(d+\gamma_1)^2}$$

$$=\frac{1}{2}\cdot\frac{\gamma_1^3}{d^2(d+\gamma_1)^2}\left[(B-A)[(B-dk)^2+(B-dk)(A-dk)+(A-dk)^2\right]$$

but we let $A = p^* - c$ and $B = p^* + s - c$

$$\Delta\omega_1-\Delta\omega_0=\frac{1}{2}\cdot\frac{\gamma_1^3}{d^2(d+\gamma_1)^2}\cdot(s)\cdot\left[3d^2k^2-3dk(A+B)+(A^2+AB+B^2)\right]$$

$$=\frac{1}{2}\cdot\frac{\gamma_1^3}{d^2(d+\gamma_1)^2}\cdot(s)\cdot\left[3d^2k^2-3dk(A+B)+(A-B)^2+3AB\right]$$

$$=\frac{1}{2}\cdot\frac{\gamma_1^3}{d^2(d+\gamma_1)^2}\cdot(s)\cdot\left[3d^2k^2-3dk(2p*-c)+s^2+3(p*+s-c)(p*-c)\right]$$

$$= \frac{1}{2} \cdot \frac{\gamma_1^3}{d^2(d+\gamma_1)^2} \cdot (s) \cdot \left[3[d^2k^2 - 2dk(p^*-c) + 2dkc + (p^*-c)^2 + s(p^*-c)] + s^2\right]$$

$$= \frac{\gamma_1^3}{2d^2(d+\gamma_1)^2} \cdot (s) \cdot \left\{3\left[(dk - p^* + c)^2 + 2dkc + s(p^*-c)\right] + s^2\right\}$$

References

Arnason R. (1998) "Fishery Subsidies, Overcapitalization and Economic Losses." **Paper presented at the workshop on Overcapacity**, Overcapitalization and Subsidies in European Fishery.

Food and Agriculture Organization (2004). **Technical Consultation on the Use of Subsidies in the Fishery Sector.** Global project for the study of impacts of fishery subsidies.

Gordon, H. (1953). "The Economic Theory of Common Property Resource: The Fishery." **Journal of Political Economy**. Vol. 62, pp. 124-142.

Harris, J. (2007). "Trade and the Environment." Encyclopedia of Earth.Eds.Cutler J. Cleveland. **Environmental Information Coalition**, National Council for Science and the Environment, Washington, D. C..

International Centre for Trade and Sustainable Development (2006). "Fishery, International Trade and Sustainable Development." **Policy discussion paper**.

Israel, D. C. and Banzon, C. P. (2002). "Overfishing in the Philippine Marine Fishery Sector." **Final Report** submitted to Economy and Environment program for Southeast Asia.

Porter, G. (2004). "Incorporating Impacts on Resources into Disciplines on Fishery Subsidies: Issue and Options." **A discussion paper**. Economics and Trade Branch, United Nations Environment Program.

Tallontire, A. (2004) "Trade Issues Background Paper: The Impact of Subsidies on Trade in Fishery Products." Policy Research - Implications of Liberalization of Fish Trade for Developing countries.

Yagi, N. (2002) "Sustainable Development and Subsidies in the Fishery Sector - A case in Japan." **Working project** submitted to Fishery Agency, Government of Japan.