A BIOECONOMIC ANALYSIS ON THE EVALUATION OF BUYBACK PROGRAM IN THE KOREAN FISHERIES: SHOULD IT BE STOPPED OR CONTINUED?

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ABSTRACT

This study is aimed at evaluating the effectiveness of buyback program implemented last during a 10-year period using a bioeconomic model. Aggregate fisheries stocks are assessed by the surplus-production model and a standardized aggregate harvest function is used in the bioeconomic model. The simulation results indicate that the fisheries stocks are still in the declining trend and more vessels must be decommissioned. In order to help government policymakers in planning a new vessel buyback program, three alternative buyback policies are additionally simulated. Each policy's biological and economic impacts projected over a 25-year period are analyzed and compared one another.

Keywords: Bioeconomic model, Buyback program, Surplus-production model

Introduction

Korean Fisheries have been managed mainly by both input control such as limited license and technical measures such as gear restriction, closed areas & seasons, and mesh size regulation. The TAC as an output control has been implemented in 1999 by which 9 species are currently managed and it is supposed that 20 species would be covered by 2010 (MOMAF, 2003).

However, in spite of these vigorous efforts, total coastal and offshore harvests have steadily declined since 1986 (figure 1). CPUE, as a proxy for the stock biomass, has also decreased, which indicates that the level of fisheries stocks has been lowered overtime.

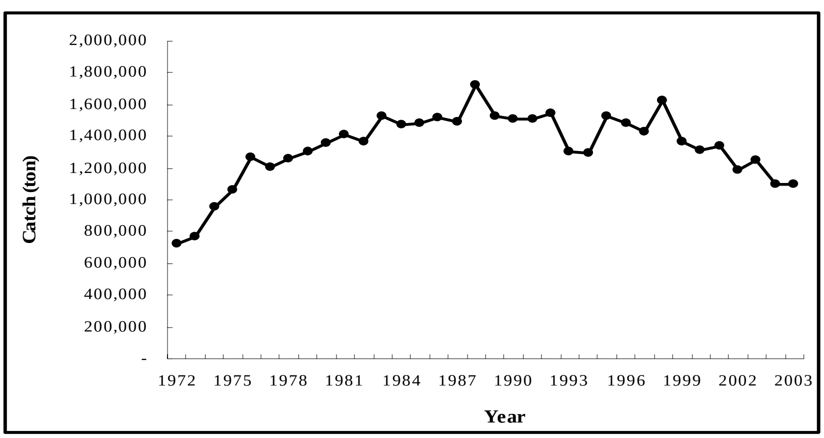

Figure 1. The change in annual total harvests overtime

On the contrary, as the fishing capacity (=the level of fishing effort) is greatly increasing (figure 2), it is concerned that the fisheries stocks would be seriously depleted in the near future.

As total harvests decrease resulting from reductions in fisheries stocks, fishing income has been reduced. In addition, as fishing costs increase significantly, the fishing business is in a seriously bad situation.[1]

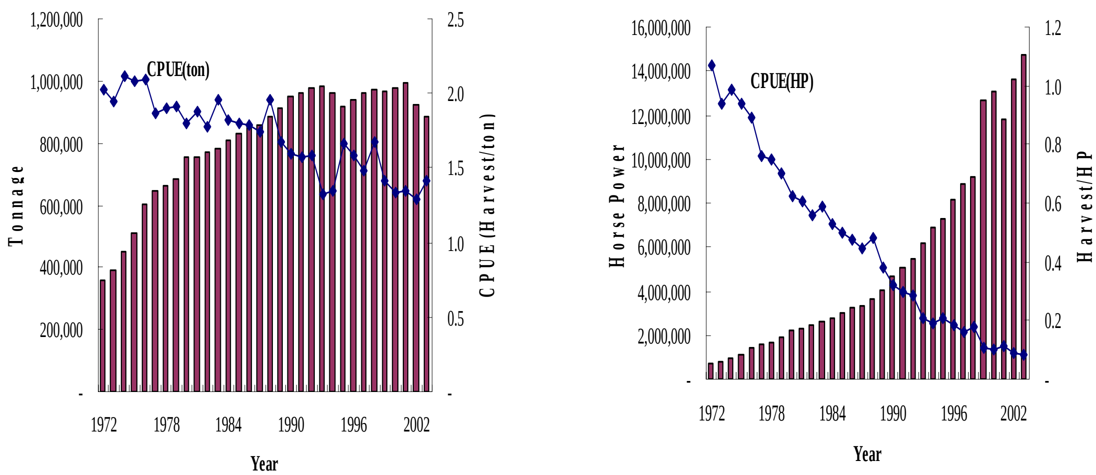

Figure 2. The changes in Vessel Tonnage, Horse Power, and CPUEs

With the background of this fisheries situation, in order to recover of the fisheries stocks, Korean government implemented the vessel buyback program from 1994 to 2003. Total 2,562 vessels (offshore vessel 1,987 and coastal vessel 575, respectively) were decommissioned (Table 1). However, concerns are occurring whether a last 10-year period buyback program has been effective to increase the fisheries stocks. In addition to this, policy issues are debated on whether the vessel reduction program must be continued or stopped. If continued, how many vessels must be decommissioned?

Table 1: Number of decommissioned Vessels (1994~2003)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Offshore Vessels	0	6	26	87	96	730	123	551	299	69
Coastal Vessels	54	111	110	48	63	0	42	68	43	36
Total	54	117	136	135	159	730	165	619	342	105

Source: Cho, et al. (2003)

This study is aimed at answering these policy questions by evaluating the impact of the vessel buyback program implemented during a last 10-year period and by predicting the effectiveness of additional vessel buyback programs. A bioeconomic modeling approach is used in the study. This is because, as already well known, a bioeconomic model shows a joint biological and economic impacts by analyzing changes in fisheries stocks and fishing incomes. By its usefulness, a bioeconomic modeling approach has been widely used in studies on the vessel reduction program (Guyader, Daures, and Fifas, 2002; Holland, 1999; Sun, 1999; Anderson, 1998; Hills and Wium, 1998).

In estimations of the additional buyback programs, different scenarios are separately established and biological and economic impacts of each scenario are evaluated. Coastal and offshore fish stocks are integrated into one stock as aggregate fisheries stocks in the study. In the analysis, first, the level of aggregate fisheries stocks is estimated by the ASPIC surplus-production model. Second, with uses of variables resulted from an aggregate stock assessment model, a bioeconomic model is developed in order to evaluate the effectiveness of vessel buyback programs.

Bioeconomic Model

Estimation of Aggregate Fisheries Stock

Aggregate fisheries stocks are estimated by the ASPIC surplus-production model. ASPIC is a computer program that fits a non-equilibrium logistic (Schafer) production model to catch and effort data. It seeks to maximize the fit between the observed catch and the indices of abundance by estimating two parameters: the maximum population size or carrying capacity (K) and the intrinsic rate of population growth (r).[2] Biological reference points can be calculated from the production model parameters:

$$MSY = K \cdot r/4 \quad \text{(Eq. 1)}$$
$$X_{MSY} = K/2 \quad \text{(Eq. 2)}$$
$$F_{MSY} = r/2 \quad \text{(Eq. 3)}$$

Total catch data and CPUE (catch/tonnage) data are used in the estimation.

Model results show that estimated catch is exactly same with observed catch data (Figure 3) and as R-square is 0.794, the model was statistically fitted very well. In addition, the environmental carrying capacity (K) of aggregate fisheries stocks is estimated at 57,240,000 tons and the estimated intrinsic growth rate (r) is 0.072 (Table 2).

The current level of fisheries stock (X_0) is estimated to be less than 80% of the level of stocks that produces a maximum sustainable yield (X_{MSY}), which indicates that the fisheries stocks would be in overfished status. The current fishing mortality (F_0) is predicted to be greater that the level of fishing mortality that sustains a maximum yield (F_{MSY}), which implies that overfishing is occurring.

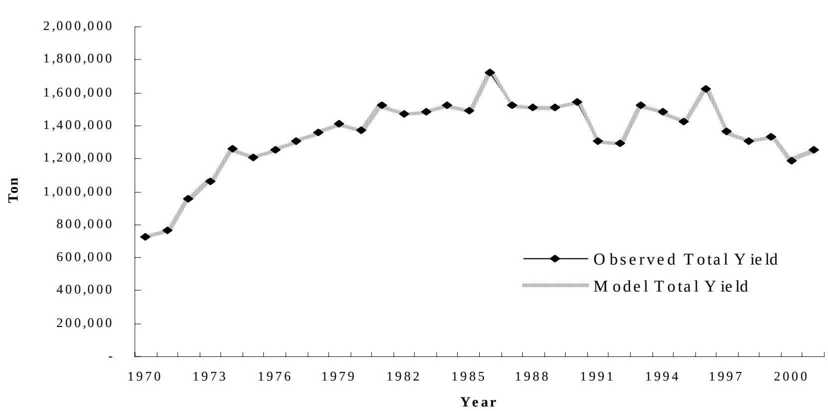

Figure 3. Observed total catch and Estimated total catch

Table 2: Results of ASPIC Surplus-Production Model

Parameter	Estimate	50% Lower CL	50% Upper CL
K	5.724E+07	4.881E+07	3.429E+08
R	7.200E-02	1.154E-02	8.222E-02
MSY	1.030E+06	1.000E+06	1.060E+06
X_{MSY}	2.862E+07	2.440E+07	1.715E+08
F_{MSY}	3.600E-02	5.769E-03	4.111E-02
X_0/X_{MSY}	7.877E-01	3.821E-01	8.842E-01
F_0/F_{MSY}	1.534E+00	1.342E+00	3.219E+00

Biological and Economic Functions

Growth Function

The general Schaefer function is used in the study as a growth function using variables estimated by the ASPIC model.

$$G(X_t) = r \cdot X_t \cdot (1-X_t/K) \qquad \text{(Eq. 4)}$$

Harvest Function

The function of aggregate fisheries harvest is assumed to be lineally proportional to the fisheries stock (X) and the level of fishing effort (E) as indicated in equation 5.

$$H_t = q \cdot E \cdot X_t \qquad \text{(Eq. 5)}$$

Where, the q is a catchability coefficient, the variable E represents the level of fishing effort, and X_t refers the fisheries stock in period t. The level of fishing effort (E) is defined as the total fishing days (= number of vessels・days per trip・number of trips).

Table 3: Total number of Vessels, Tonnage and Horsepower by various tonnage classes (2003)

Various Tonnage Classes	Vessels		Tonnage		Horse Power	
	Number	%	Ton	%	Horse Power	%
Under 5 ton	75,864	85	127,739	28	8,791,508	64
5~10 ton	7,653	9	57,864	13	1,998,550	15
10~20 ton	1,411	2	20,329	4	417,149	3

20~30 ton	1,005	1	25,605	6	826,316	6
30~50 ton	827	1	32,579	7	363,154	3
50~100 ton	1,463	2	110,345	24	777,338	6
100~200 ton	515	1	86,953	19	528,901	4
Total	88,738	100	461,414	100	13,702,916	100

Source: MOMAF (2003)

Because offshore and coastal vessels vary with both tonnage and horse power per vessel as shown in Table 3, simply reductions in number of vessels are not meaningful when evaluating the impact of vessel buyback program. Therefore, a standardized vessel is estimated using a weight-average with tonnage and numbers of standardized vessels for each class are calculated.

Cost Function

Fishing costs are calculated as a trip cost of standardized vessel and it is assumed to be a linear function of trip cost (a) and fishing effort (E_t) as shown in equation 6.

$$C(E_t) = a \cdot E_t \qquad \text{(Eq. 6)}$$

Where, E_t is the level of fishing effort in period t and a is a trip cost, which is also standardized by averaging a trip cost of each vessel class using tonnage as a weight, then it is averaged between 2001 and 2003. An average trip cost of standardized vessel is estimated to be 4.13 (million wons).

Stock Dynamics Function

Based on the surplus-production model, the function of aggregate fisheries stocks dynamics is the follwing.

$$X_{t+1} = X_t + G(X_t) - H_t \qquad \text{(Eq. 7)}$$

Where, X_t and X_{t+1} represent the fisheries stocks in period t and t+1, respectively. $G(X_t)$ is the growth function in period t, and H_t is the harvest in period t. Suppose equations (4) and (5) are substituted for the equation (7), it can be rearranged into the equation (8).

$$X_{t+1} = X_t + r \cdot X_t \cdot (1 - X_t/K) - q \cdot E \cdot X_t \qquad \text{(Eq. 8)}$$

When harvests are greater than growths in period t, the fisheries stocks in period t+1 are decreased. On the contrary, when growths are greater than harvests, the fisheries stocks are increased.

Revenue Function

Annual fishing revenues (TR) are calculated by multiplying harvests (H_t) in period t and a market price (p),

$$TR_t = H_t \cdot p \qquad \text{(Eq. 9)}$$

The market price (p) is an averaged price between 2001 and 2003, dividing total fishing revenues by total harvests. In addition, total profits (TP) are calculated by subtracting total fishing costs from total fishing revenues. In order to analyze the economic impact of vessel buyback program, net present value of total profits for a 25-year period discounted by 4% interest rate (δ) is calculated as seen in equation 10.

$$NPV = TP_0 + TP_1/(1+\delta) + TP_2/(1+\delta)^2 + TP_3/(1+\delta)^3 + \cdots + TP_{24}/(1+\delta)^{24} \qquad \text{(Eq. 10)}$$

Results

Scenarios

The evaluation of vessel buyback program using a bioeconomic model is divided largely into two parts. In first part, a with-without analysis for the vessel buyback program implemented last during 10 years is accomplished. Where, supposing the government did not apply the vessel reduction program from 1994 to 2003, using the level of fishing effort in 1994, changes in fisheries stocks and fishing profits are analyzed and compared. In second part, the impacts of additional buyback programs are evaluated by scenario as shown in Table 4. Scenario 1 is to assume no more buyback program since 2003. It is a base case for comparison of another scenarios. Scenario 2, 3, and 4 are to estimate the effectiveness of buyback programs when reducing standardized vessels by 10%, 20%, and 30% in 2004 in addition to the scenario 1.

Table 4: Scenarios for future buyback program

Scenario 1	No more vessel reductions after 2003
Scenario 2	10% reduction of standardized vessels in 2004 (total 46,104 tons reduced)
Scenario 3	20% reduction of standardized vessels in 2004 (total 92,207 tons reduced)
Scenario 4	30% reduction of standardized vessels in 2004 (total 138,311 tons reduced)

Results of the With-Without Analysis

Model results show that suppose no buyback program has been implemented, the fisheries stocks would be more significantly decreased (Table 5). Specifically, the fisheries stocks are predicted to be approximately 61% of X_{MSY} compared to the current stocks, 71% of X_{MSY}. In addition, economic gains are estimated to be higher since the program has been established, which is due to the increase in harvests resulting from the increase in fisheries stocks. As a result, incomes per vessel have been also increased.

However, although the decreasing rate of fisheries stocks has been lowered by the buyback program, the fisheries stocks are estimated to be still in the decreasing trend. The reasons the buyback program could not contribute to the recovery of fisheries stocks are pointed out in variety such as limitation of government management, no controls on illegal fishing, and so forth (Cho, et al., 2003). But, we think a major problem is that a specific/detailed objective of the program was not established and annual reductions in vessels were conducted obstinately without any scientific research and impact analysis for the recovery of fisheries stocks.

Table 5: Results of the With-Without Analysis

	Fisheries Stocks after 10 years (Million tons)	Total Profits (100million Won)	Profits per Vessel (100million Won)
Without Buyback Program	17.9 (61%)	59,008.8	4.7
With Buyback Program	20.4 (71%)	59,403.1	6.1

Note: (1) Figures in parentheses are a percentage to X_{MSY}
(2) Total Profits are a net present value of returns over a 10-year period, discounted by 4% interest rate
(3) Profits per vessel are values divided total profits by number of standardized vessels

Effectiveness of Scenarios

According to the results of the with-without analysis, the vessel buyback program is needed to continue in order to increase both fisheries stocks and economic welfares. For this reason, scenarios on the buyback program, as seen in Table 4, were analyzed to evaluate the impact of additional vessel reductions. Model results are focused on increases in fisheries stocks compared to X_{MSY} and increases in economic gains. Results are presented in <Figure 5> and <Table 6>.

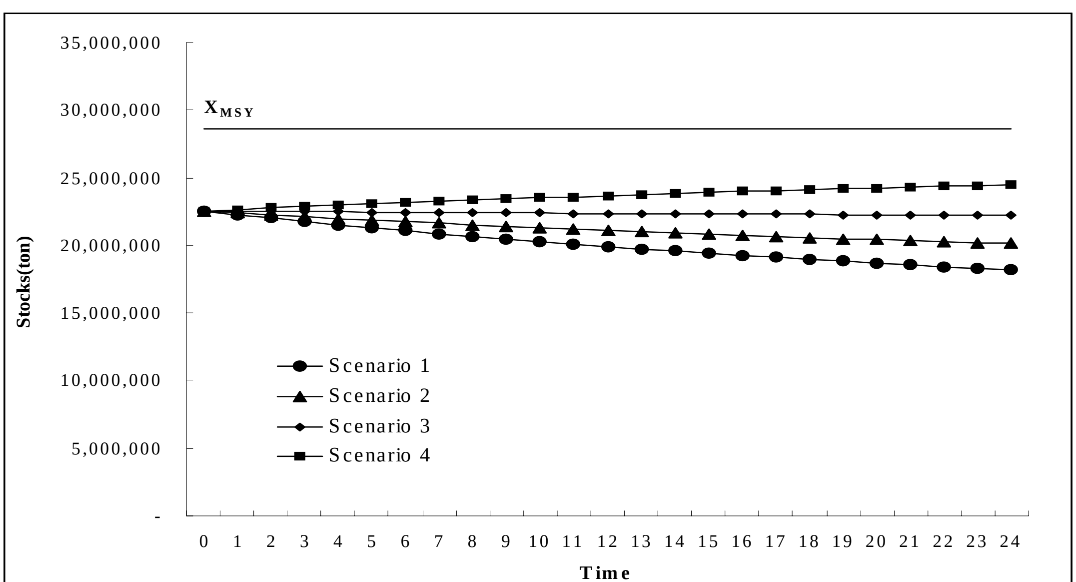

Figure 5. The change in fisheries stocks by each scenario

Table 6: Model Results

	Fisheries Stocks After 10 years (Million tons)	Fisheries Stocks After 25 years (Million tons)	Total Profits (100million Won)	Profits per Vessel (100million Won)
Scenario 1	20.3 (71%)	18.1 (63%)	93,205.7	9.6
Scenario 2	21.3 (74%)	20.1 (70%)	102,265.0	11.7
Scenario 3	22.4 (78%)	22.2 (78%)	108,139.5	13.9
Scenario 4	23.5 (82%)	24.5 (86%)	110,518.7	16.3

Note: (1) Figures in parentheses are a percentage to X_{MSY}
(2) Total Profits are a net present value of returns over a 25-year period, discounted by 4% interest rate
(3) Profits per vessel are values divided total profits by number of standardized vessels

Scenario 1 is analyzed as a base case for comparison of another scenarios. Suppose there is no more vessel reductions since 2004 after implemented during a last 10-year period, the fisheries stocks are predicted to decline steadily (Figure 5). Concretely, the stocks would be reached at 71% of X_{MSY} in a 10-year period and would become 63% after a 25-year period. Total profits are predicted to be 93,205.7 (00million Won) and profits per vessel are 9.6 (00million Won).

Suppose 10% of standardized vessels are decommissioned in 2004 in addition to the scenario 1, total 46,104 tons are scrapped additionally. However, in spite of this amount of reductions, the fisheries stocks would be still decreased (X_{25}/X_{MSY} = 0.74 in 10 years and X_{25}/X_{MSY} = 0.7 in 25 years). But, the decreasing rate of stocks becomes lowered. Total economic gains are predicted to be higher than under the scenario 1, it is because harvests are increased resulting from a relatively low rate decreasing of fisheries stocks. Due to increases in total profits and reduced number of vessels, profits per vessel are increased.

When 20% of standardized vessels are decommissioned in addition to the scenario 1, total 92,207 tons are scrapped additionally. Model results show that the fisheries stocks remain stable without decreasing or increasing (X_{25}/X_{MSY} = 0.78 in 10 years and X_{25}/X_{MSY} = 0.78 in 25 years). Due to the relatively higher stocks compared to the Scenario 1 and 2, total profits are predicted to be higher. Additionally, profits per vessel are increased more than under the scenario 2. This scenario implies it is possible to increase the fisheries stocks if more vessels would be reduced.

If 10% more reduced in addition to the Scenario 3, total 138,311 tones are reduced. Under this scenario, the fisheries stocks are predicted to increase overtime (X_{25}/X_{MSY} = 0.82 in 10 years → X_{25}/X_{MSY} = 0.78 in 25 years). However, X_{MSY} would not be attained even after a 25-year period. It implies more vessels must be scrapped in order to achieve the target X_{MSY}. Due to the increase in stock biomass and harvests, total profits are shown to be largest among scenarios and profits per vessel are too.

Summary and Conclusion

The with-without analysis on the buyback program established from 1994 to 2003 shows that the fisheries stocks would be decreased continuously even though the decreasing rate is lowered. It means the program was not sufficient to recover the fisheries stocks and more vessels must be decommissioned in order to increase the stocks and economic gains. Therefore, this study tried to evaluate the biological and economic impacts of scenarios where more vessels are reduced in 2004 by 10%, 20%, and 30% respectively. Results show even 20% standardized vessels (92,207 tons) are decommissioned, the fisheries stocks could not be increased and remain stable or decreased. When 30% vessels are scrapped, the stocks finally begin to increase. But X_{MSY} could not be achieved after a 25-year period.

In conclusion, more analyses are accomplished in order to investigate how many vessels must be reduced to attain X_{MSY} after 25 years. Model results show that in order to attain X_{MSY}, approximately 46% standardized vessels (total 212,076 tons) must be decommissioned in 2004, one period (Table 7). If it is impossible to scrap this amount of vessels in a year, vessels could be reduced within a few years. Results show that 12% vessels must be decommissioned annually during a 5-year period and 20% must be scrapped annually during a 3-year period in order to attain X_{MSY}. Interestingly, total profits and profits per vessel become larger when vessels are decommissioned in shorter period.

Table 7: Alternative Vessel Reduction Ways to Achieve X_{MSY} after a 25-year period

	Fisheries Stocks After 10 years (Million tons)	Fisheries Stocks After 25 years (Million tons)	Total Profits (100million Won)	Profits per Vessel (100million Won)
46% reductions in 2004	25.1 (89%)	28.5 (100%)	106,232.5	20.3
Annually 12% reductions during a 5-year period	24.4 (86%)	28.1 (100%)	103,575.7	12.1
Annually 20% reductions during a 3-year period	24.8 (88%)	28.4 (100%)	104,656.6	13.3

Note: (1) Figures in parentheses are a percentage to X_{MSY}
(2) Total Profits are a net present value of returns over a 25-year period, discounted by 4% interest rate
(3) Profits per vessel are values divided total profits by number of standardized vessels

This study simply analyzed the impact of the vessel buyback program on the fisheries stocks and investigated the changes in fisheries stocks by reducing numbers of standardized vessels. However, if the vessel reduction program is implemented with other management measures effectively, an expected biological effectiveness would be more increased.

Besides, in order to achieve efficiently an objective of the vessel buyback program, the specific target fisheries stock must be established and performed systematically with a preliminary analysis. In addition, additional increases in fishing efforts such as increases in tonnages and horse powers must be restricted and illegal fishing must be also prevented.

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Endnotes

1. Specifically, the ROI (Return of Investment) of offshore fishery has been significantly dropped from 20~30% in 1980s to under 10% since 2000 and the dept/capital ratio over exceeded 50%. Furthermore, fishing incomes of coastal small-scale fishermen has been seriously reduced due to decreases in production and the dept/capital ratio has increased from 58.6% in 1997 to over 65% in 2003.
2. Many treatments of surplus-production models, including the works of Schaefer, have assumed that the harvest taken each year could be considered the equilibrium harvest, at least for the purposes of parameter estimation. A notable exception is the GENPROD model of Pella and Tomlinson, which does not use the equilibrium assumption. ASPIC is

a computer program that fits a non-equilibrium logistic production model to catch and effort data in a manner similar to GENPROD. For a stock that is heavily exploited, the results of a non-equilibrium model can differ markedly from those of an equilibrium model. In general, equilibrium models can overestimate MSY when used to assess a declining stock.