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A REAL OPTIONS APPLICATION TO THE FISHING VESSEL SCRAPPING DECISION OF VESSEL BUYBACK PROGRAMS

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Key words: real options, vessel buyback program, vessel-scrapping decision, profit uncertainty.

ABSTRACT

This paper adopts the real options approach to examine vessel owners behavior in deciding whether to participate or not in the vessel buyback programs. The model allows us to investigate profit uncertainty in a decision to retire an aged vessel and the underlying value of waiting for new information about the profitability of such a change, which may affect the willingness of vessel owners to participate in the vessel buyback programs. Our analysis shows that the government needs to pay more attention to profit uncertainty, which may invalidate the vessel buyback program that does not take it into account. This also contributes to explain the failure of most of the vessel buyback programs aimed at encouraging the retirement of aged vessels in Taiwan. We also evaluate the value of willingness to accept of vessel owners and its policy implications are discussed.

INTRODUCTION

Overcapitalization and overcapacity in the fisheries have been found in recent years. Mace (1997) points out in her address in the World Conference on Fisheries that as much as 70% of world's fisheries are in different degrees of stress (fully exploited, over exploited, or in recovery). Concerning with this fact and its impacts on fish stocks has reported in the literature (FAO, 1997). In Taiwan, the prohibition policy of building new fishing vessels without quota has been enacted. By 1990 there were 4,824 powered fishing vessels operated more than 15 years, which represent 35% of the total vessels. Because of low efficiency and diminished revenue in Taiwan's offshore fisheries, the smuggling activities have caused fisheries management and society security problems. In order to improve and stabilize this phenomenon, Fisheries administration authorities has implemented the vessel buyback program for 5 years from 1991 to 1995. Under this program, purchase of 2, 337 vessels has granted at NT$12,000 per ton for each vessel. However, the purchased vessels can hardly reach the expected buyback goal of 10,000 powered fishing vessels. This is due to the fact that vessel owners are unwilling to retire those aged fishing vessel automatically, which makes the goal of the program difficult to achieve (Dai, 1997).

Our goal in this paper is to investigate the decision of fishing vessel owners to retire the aged vessels in the presence of profit uncertainty. We accomplish this by using the real options approach to analyze under profit uncertainty how vessel owners are willingly to give up aged vessels. In the paper, the main source of profit uncertainty comes from vessel owners' shortage of full information about evaluating the future state of fish stocks and fish prices. Another source is that vessel owners may obtain political windfall due to the industrial characteristics of fishery in Taiwan. We explain why the effect of vessel buyback program was not significant. The program purchased, for example, only 96 vessels representing 0.72% of total number of vessels in 1995.

In related literature, Holland, Gudmundsson, and Gates (1999) concluded that buyback programs are generally not an effective way to solve the problems of too many vessels and too much fishing power. They do not explain the reason why buyback programs are unsuccessful from the theoretical viewpoint. Li (1998) uses the model of option value to analyze the case, where the mutual cooperated fishing proprietors will become more conservative in their fishing actions in order to elevate their efficiency in fishing under the uncertainty of fishing resources stock with no another fishing fleets entering into the fishing ground. Chuang (1999) introduces a discontinuous choice model to evaluate the buyback program of Taiwanese fishing fleets, pointing out that the goal of buyback program can be

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achieved effectively by considering both economic conditions and the fishing vessel value. Sun (1998) shows that neither the program to restrict the building of new vessels nor a combination of this program with the vessel retirement and buyback program is enough to avoid overfishing for Taiwan's offshore fisheries. She concludes that a passive vessel retirement and buyback program in Taiwan's offshore fisheries is not an effective resource stock recovery program. Moretto (2000) applies a real options model to analyze the vehicle-scrapping programs aimed at encouraged the retirement of old cars. Considering stochastic net benefits of driving service, vehicle owners would wait for the net benefit information, which may substantially affect the scrapping time.

This paper follows the real options approach which has been developed by Dixit (1993), Dixit and Pindyck (1994), Trigeorgis (1999), and Moretto (2000), to set up a stochastic vessel owner's decision model. This model can be use to account for the effect of vessel buyback programs which affect the retirement policy of vessel owners by considering the uncertainty of waiting value. By our setting, the paper can determine a vessel owner's willingness-to-accept (WTA) price for a vessel buyback program by the numerical method. The results explain the reason why vessel buyback programs in Taiwan cannot be accomplished effectively. The main explanation for the failure of vessel buyback programs is because the uncertain fishing net profit causes the waiting value which makes vessel owners postpone their willingness of retiring aged vessels.

The paper is organized as follows. Section 2 discusses and reviews the experience of vessel buyback programs in Taiwan. In this section we provide a description of the problem of fisheries management and the implementation of vessel buyback programs. Section 3 develops a stochastic model of retirement aged vessels. An analysis of the retirement decision for vessel owners is derived in this section. Section 4 presents some numerical simulation analysis in support of our conclusions. Section 5 concludes with a brief summary.

VESSEL BUYBACK PROGRAMS IN TAIWAN

The government of Taiwan has invested heavily in the fishing industry to boost its commercial fishing fleet since the 1950s[1]. In Figure 1 we use four indices to represent fishing industry capacity including number of boats, tonnage, horse power, and total landing. Using 1970 as the base year, the index numbers are the ratio of the quantity of each measure for a year to that of the based year, respectively. Technological improvements in engine design cause the total horse power to rise sharply. The discrepancy in growth rates between number of vessels and vessel tonnage implies that large steel vessels have replaced wooden vessels in recent years. The promotive policy adopted by the Taiwan government has greatly increased fish harvest till the late 70s. The recent trend in harvest seems to suggest that the growth of the fishing industry has exerted pressure on fish stocks.

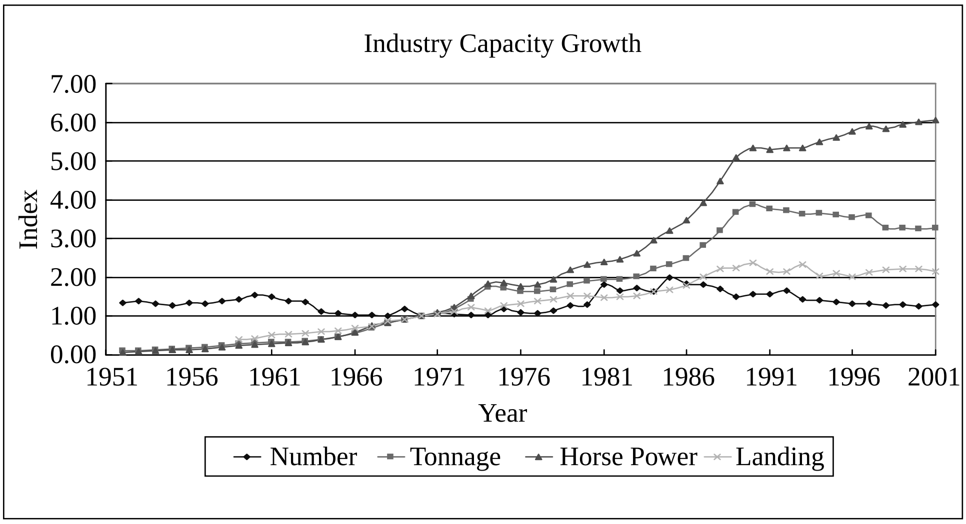


Fig. 1. Capacity growth of taiwan fishing industry [6].

[1] Low interest loans were provided to fishermen for upgrading vessels and procuring equipment. A substantial fuel subsidy was implemented to cut operating costs and increase profits. These measures have increased the industrial capacity.

In response to the decline in the profit of fishing operations, in 1991, 3 billion NT dollars was appropriated to implement a five-year (1991-1995) buyback program in an effort to reverse the trend of excessive capitalization and growth[2]. The program was designed to achieve multiple purposes besides reducing fishing capacity and protecting fishing resources. First, the fluctuation in profits had leaded fishing vessel owners to do smuggling and other illegal activities, which were expected to be curtailed by the program. Second, the buyback program in its second year targeted high seas drift net vessels to comply with the UN resolution that banns their uses[3]. Third, the buyback program was expected to accelerate the retirement of old vessels for reducing vessel site congestion and to enhance the amenities in fishing harbors.

The buyback program was publicized each year for a period of twenty days for the first year and thirty days thereafter to keep the fishermen informed. Applicants were required to register at the fishery department of the local county government. Application was then submitted to the Council of Agriculture for approval. However, no historical catch records or revenues were used for screening or evaluating the applicants. The approved vessels along with their licenses were turned over to the local government. The purchased vessels were then scrapped in a way that those were burned and those made of steel or FRP were submerged to the sea to form artificial reefs. Figure 2 shows details of operational procedures for the buyback program.

Different criteria were applied to target specific types of vessels. For 1991-1992, all vessels were eligible for the program as long as the owner had a legal fishing license. In 1993, only vessels at least 15 years old could apply for the program. In 1994, vessel age for eligibility was lowered to 12 years due to low participation in the program. In addition to eligibility criteria, priorities were also set for different ages and types. In 1991, vessels older than 20 years were given the highest priority. Older drift-net boats were given higher priorities next year to comply with the UN resolution banning their uses. In 1993, priorities were assigned to assure that active vessels were bought back. Captains with licenses that had expired before Nov. 17, 1990 were assigned the third priority if they agreed to not engage in fishing activities anymore. Similar schemes were also adopted in 1994.

Applicants in vessel buyback programs are usually voluntary. They evaluate the total benefits offered by the program and choose to give up a vessel and fishing license as they see fit. The opportunity cost of retiring the vessel is simply the profit that could have been realized if the vessel continues its fishing operation. For a rational applicant, the comparison of the opportunity cost and the program benefits determines the decision for submitting an application. If the buyback offer is greater than the profit that a vessel can generate over the remainder of its life, the vessel owner will forgo the vessel and participate in the program, and vice versa.

In reality, an effective vessel buyback program needs careful design and implementation. Vessel buyback programs in Taiwan were well funded and the programs had been revised and improved during its five-year run. In this study, we have surveyed the economic incentives for vessel owners to apply the vessel buyback program. Among the 108 full-time vessel owners who engage in commercial and recreational fisheries, only 25 of the response think that the buyback scheme is reasonable. Referring to Table 1, the minimal acceptable price for participating in the vessel

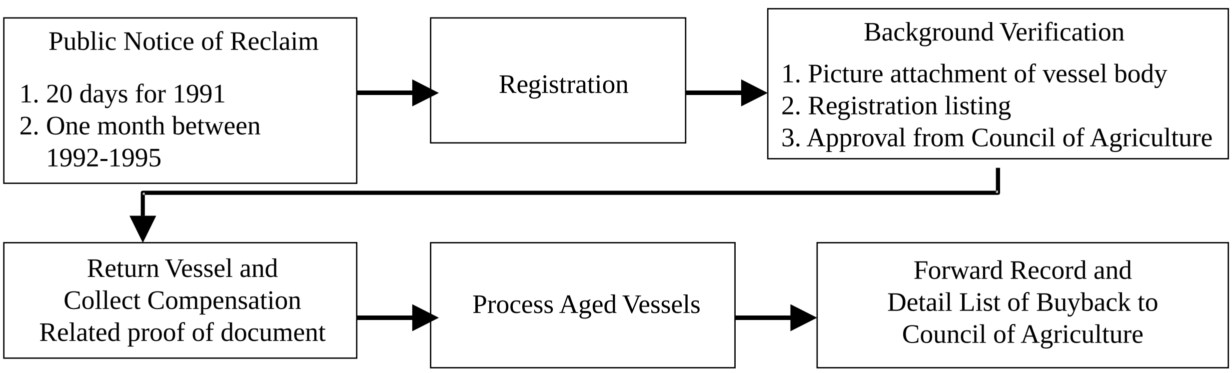


Fig. 2. Operational procedures of the vessel buyback program.

[2] Taiwan government issued a directive at the 6th National Security Convention held on October 8th, 1990 to control the number of vessels through a buyback program.

[3] In order to comply with international fishery protection activities, gill net of large mesh size and squid gill net have been forbidden in Taiwan since 1993.

Table 1. Respondent's feedback on the buyback program and intention to participate

Tonnage of Vessel	Is NT$12,000 Per Ton Reasonable			Acceptable Incr領tive for Participation in the Buyback Program						Participant in the Buyback Program
				Net Fishery			Line Fishery			
	Yes	No	Total	Min. (NT$)	Max. (NT$)	Ave. (NT$)	Min. (NT$)	Max. (NT$)	Ave. (NT$)	
0- 5	4	16	20	10,000	25,000	16,750	12,000	28,000	22,500	6
5-10	11	24	35	16,000	35,000	21,750	18,000	40,000	26,500	10
10-20	6	28	34	15,000	40,000	25,000	16,000	50,000	28,500	9
20-50	4	15	19	12,000	30,000	19,500	16,500	25,000	21,000	7
Total	25	83	108	10,000	40,000	21,750	12,000	50,000	24,375	32

Source: These surveys were conducted in June and October 1998 respectively.
Note: Net fishery includes trawl net, gill net, purse seine, torch light, and large scale; line fishery includes long line, pole and lines boote, squid jigging, and troll line.

buyback program is NT$12,000 granted by the government. Following the introduction of this buyback program, a market for such vessel trade is created since the total vessel tonnage is limited and new entry is prohibited in 1989 unless licenses transfer from old vessels. The highest price for the line fishery vessel between 10-20 tonnage is about NT$285,000. Vessels of this category are sold to the market for recreational fishing vessels. However, the lowest price for the net fishery vessel between 0-5 tonnage is about NT$ 16, 750. Vessels of this category are heavily traded in the market. The overall average acceptable price for applying the vessel buyback program is NT$24,375 which is well above the NT$12,000 buyback price granted by the government. But this large difference, in our options, reflects the fact that vessel owners can do more political actions or through negotiating with the government to obtain more compensations for participating in vessel buyback programs.

STOCHASTIC MODEL

From the point of view of real options, vessel owners have the right but no obligation to accept the buyback option. The decision of vessel owners would depend on the degree of "deep in the money" of that option. We assume that in a specific fishing industry, all of the vessel owners are willing to cooperate to work out the fishing retirement decision in the industry. The sense of mutual cooperation will lead to organize the community fisheries co-management system so that we are able to take this mutual cooperation behavior as the one single vessel owner who has purchased vessels for a suitable operation period, and retire an aged one to replace the same model of new one. This ownership cycle is assumed to be infinite, which states that the time horizon for the vessel owner's decision is infinite. This assumption follows the basic assumption in both Li (1998) and Morreto (2000) that would take the owner's aged vessel retirement behavior as the retirement behavior of real asset investment. In fact, Munro (1996) shows that it would be workable in the practice of community fisheries co-management system in his research. Munro's result provides our paper with a practical ground to assume that the vessel owners' vessel-scrapping decision in the specific fishery industry (or in the specific fishing community) can be seen as if a vessel owner's vessel-scrapping decision. This would simplify the model addressed in the paper and allow us to see how profit uncertainty affects the owner's vessel-scrapping decision. As in Moretto (2000), we model the stochastic fishing profit π following a geometric Brownian motion:

$$d\pi_t = \mu\pi_t dt + \sigma\pi_t dw_t,\ \mu \le 0,\ \pi_0 = m \quad (1)$$

where dw_t is the increment of a standard Wiener process (Dixit, 1993); μ is the expected growth rate of the trend value of stochastic process; σ is the standard deviation of the fishing profits. Thus, equation (1) indicates that the fishing profit of a new vessel has been known and expressed by m. In addition, McDonald and Siege (1986) has shown that π_t is log-normally distributed and $E_0(\pi_t) = me^{ut}$. Therefore, the expected fishing profit of vessel owners declines as the vessel ages due to fishing environmental factors or market conditions. For instance, fishing environmental factors (i.e., stock collapse) cause higher risks in fishing operations and result in higher operating costs, or the marketing conditions (i.e., fishing labor shortage) lead to increasing fishing labor costs and the falling-off fishing cost, those factors all influence the vessel owners' net profit π_t.

Now, starting at time t, the vessel owner's fishing profit will be $\pi_t = \pi$ and the expected present value of the stream of fishing profits for the owner will be

$$F(\pi) = E\left\{\int_t^{\infty} \pi_s e^{-r(s-t)}\,ds - \sum_i C e^{-r(s_i - t)} \,\middle|\, \pi_t = \pi\right\} \tag{2}$$

where C is the cost of buying new fishing vessel for the owner; r is the owner's discount rate; and s_i is the time when a new vessel is bought and the cost C is paid. We design a decision rule which states that whenever π_t reaches a lower level of profits $b < m$, the vessel owner is not longer optimal to keep the aged vessel. Then π_t is instantaneously shift to m at the cost C. That is, the vessel owner applies for the vessel buyback program and retires the eligible aged vessel. The owner's problem is to select optimally the lower barrier b to maximize the equation (2). The regime we describe will consist of a bang-bang control analyzed by Clark (1990) and Dixit (1993). Consequently, the aged vessel retirement decision of the owner can be delayed.

Following Dixit and Pindyck (1994) and Dixit (1993), under the condition of $\pi \in [b, \infty)$, it will obtain $F(\pi)$ through the following second order differential equation:

$$\frac{1}{2}\sigma^2\pi^2 F''(\pi) + \mu\pi F'(\pi) - rF(\pi) = -\pi \tag{3}$$

with the boundary condition $F(\infty) = 0$, and the general solution is

$$F(\pi) = G\pi^{\beta_1} + D\pi^{\beta_2} + \frac{\pi}{r-\mu} \tag{4}$$

where $\beta_1 > 0$, $\beta_2 < 0$ are roots of the quadratic equation:

$$\Omega(\beta) \equiv \frac{1}{2}\sigma^2\beta(\beta-1) + \mu\beta - r = 0 \tag{5}$$

In order to make $F(\pi)$ has the fixed estimated value when π is approaching the maximum value, $G\pi^{\beta_1}$ must be zero. In equation (4), $\frac{\pi}{r-\mu}$ is the present value of profit obtained if the owner keeps a vessel; $D\pi^{\beta_2}$ represents the profit of cycling purchased vessel and must be positive. In order to determine the lowest value of constant D and the profit level, we have to consider the following conditions:

(a) value- matching condition:

$F(b) = F(m) - C$, and

(b) smooth-pasting condition:

$F'(b) = 0$

The value-matching condition indicates that at the boundary the owner has the same evaluation for either to keep an aged vessel or to retire it when he faces the suitable retirement conditions. The smooth-pasting condition states that at the boundary it needs to meet the first order condition of equation (2). Therefore, the following two equations need to be solved:

$$D(b^{\beta_2} - m^{\beta_2}) = \frac{m-b}{r-\mu} - C \tag{6}$$

$$D\beta_2 b^{\beta_2} + \frac{b}{r-\mu} = 0 \tag{7}$$

Since $\frac{\pi}{r-\mu} > 0$, $D > 0$ is required to satisfy equation (7). Based on this result and the condition of $m > b$, we obtain $m - C(\gamma - \mu) > b$. Assuming , $b^* = m - C(r - \mu)$, which is the net value of purchasing a new vessel under certainty, i.e. the profit minus the opportunity cost of investment $C(r - \mu)$, it is clear that if the profit£kof aged vessel reaches the value of b, the vessel owner will purchase a new one because $b^* > b$. In other words, under profit uncertainty, whether the vessel owner wants to purchase a new vessel will depend on the net profit of the aged vessel if it has reached to the value of b. Therefore, under profit uncertainty, the owner will wait for obtaining much more information about the profit of the aged vessel before he decides to purchase a new one.

Obviously, the waiting value is

$W = b^* - b = m - C(r - \mu) - b.$

That is, the waiting value for vessel owners comes from the parameter value in the model under profit uncertainty.

WTA OF VESSEL OWNERS AND GOVERNMENT PURCHASING PRICE

In this section, we analyze how government offers vessel owners a buyback aged vessel program to encourage the retirement of aged vessels under the cycled period as vessel owners still own their aged vessels. We use $F(b)$ representing the owner's expected present value of profit for giving up an aged vessel, while $F(b)$ is the owner's present value of profit and $\pi \in [b, \infty)$. Therefore, in order to induce vessel owners who have got the profit up to $\pi \in [b, m)$ to accept the aged vessel buyback program offered by the government, rather than waiting for the profit π up to the value of b, the price of buyback R must

$$F(b) = R = F(\pi), \text{ or}$$

$$R \geq F(p) - F(b) \equiv U(\pi, b) \quad (8)$$

In equation (8), $U(\pi, b)$ is the willingness to accept (WTA) for the owner to accept the government buyback program. The WTA is related to the current vessel's profit π, the degree of profit uncertainty σ, a new vessel's purchasing cost C, the discount rate r, and the trend value of μ. Through calculation, equation (8) can be rewritten as

$$U(\pi, b) = D(\pi^{\beta_2} - b^{\beta_2}) + \frac{1}{r-\mu}(\pi - b) \quad (9)$$

From equation (9), we can see that when the vessel's profit reaches the value of b, $U(b, b)$. At that time, the fishing vessel owners are sure to give up their aged vessels without the buyback incentive offered by the government. As a matter of fact, even if the vessel owners have not accepted the conditions of the vessel buyback program, they will make a decision to buy a new vessel. On the other hand, if the fishing craft is new or the external factors such as smuggling activities or selling the fishing vessel oil illegally is alternative, this will cause the profit to be $\pi = m$, and then $U(m, b) = C$. In addition, we can see that when $\sigma \to 0$, that is, the fishing vessel's profit is under certainty , the WTA can be rewritten as follows:

$$U_{\sigma \to 0}(\pi, b^*) = \frac{1}{r-\mu}(\pi - b^*) \quad (10)$$

and

$$U_{\sigma \to 0}(b^*, b^*) = 0 \text{ and } U_{\sigma \to 0}(m, b^*) = C \quad (11)$$

According to equations (9) to (11), we obtain the following results:

(1) Under profit uncertainty, the vessel owners will not participate in the vessel buyback program because $U(\pi, b) > U_{\sigma \to 0}(p, b^*)$, which induces their willingness to replace new vessels in a slow pace so that the aged vessel buyback program funded by the government is hard to achieve the expected effects.

(2) The buyback price of aged vessel funded by the government should be between [0, ***C***]. We are sure that the price is related to the net profit level π_t for ship owners in the time period of t.

NUMERICAL SIMULATION

For the purpose of analyzing how the profit uncertainty affect the WTA, we set up three uncertainty parameters $\sigma = 0$ (i.e., profit is certain), $\sigma = 1$ and $\sigma = 10$; $r = 0.05$, $\mu = -0.5$, $C = 100,000$. By using equations (5), (6) and (7), we can get value of β_2, D and b. Finally, substituting these values into equation (9), we obtain the equations (12), (13) and (14) as follows.

(i). when $\sigma = 0$, we have $\beta_2 = -1$,

$$D \approx 74,967,890,560,\ b \approx 86,584 \quad (12)$$

$$U(\pi, 86584) = 74967890560(\pi^{-1} - 86584^{-1}) + 10(\pi - 86584)$$

(ii). when $\sigma = 1$, we have $\beta_2 = -0.0844$,

$$D \approx 25,345,114,\ b \approx 82,296$$

$$U(\pi, 82296) = 25345114(\pi - 0.0844 - 86584 - 0.0844) + 10(\pi - 82296) \quad (13)$$

(iii). when $\sigma = 1$, we have $\beta_2 = -0.001$,

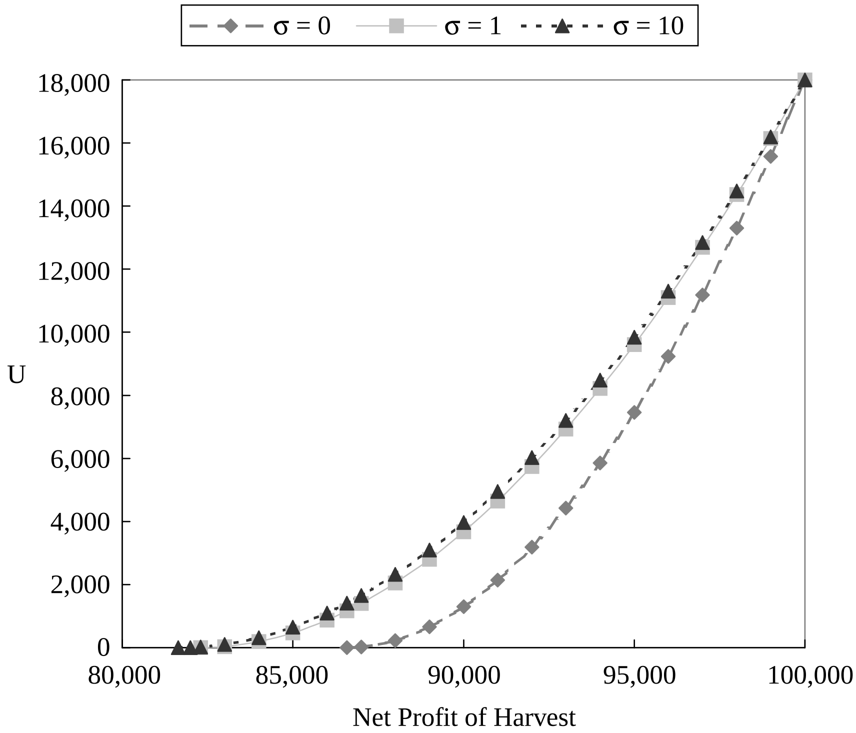
$$D \approx 825,736,578,\ b \approx 81,645.$$

$$U(\pi, 81645) = 825736578(\pi - 0.001 - 81645 - 0.001) + 10(\pi - 81645) \quad (14)$$

Substituting different profits of a vessel to equations (12), (13) and (14), we obtain the results as shown in Figure 3. This figure depicts the fact that shows the amount of WAT is increasing in£mbecause when the situation gets worse in profit uncertainty, the waiting value will be higher than expected. As a result, vessel owners should be more inclined to slow down their willingness for participating in the vessel buyback program. Therefore, the purchased price of aged vessels granted by the government should be increased to encourage vessel owners to give up their aged vessels voluntarily.

CONCLUSION

This paper is important because it shows how the profit uncertainty of vessel owners affects their decision in participating in the vessel buyback program. Our study suggests that when the government decides to implement the vessel buyback program, it should pay more attention to consider the effect of the profit uncertainty faced by vessel owners. For example, the vessel owner's profit level is the capability of making a profit for an aged vessel, which is the residual value of an aged



π	U		
	σ = 0	σ = 1	σ = 10
81,645			0
82,000			5
82,296		0	21
83,000		32	101
84,000		189	316
85,000		471	649
86,000		877	1,095
86,584	0	1,169	1,408
87,000	20	1,402	1,653
88,000	228	2,046	2,320
89,000	656	2,803	3,094
90,000	1,297	3,673	3,972
91,000	2,143	4,652	4,951
92,000	3,188	5,738	6,030
93,000	4,426	6,928	7,206
94,000	5,851	8,221	8,478
95,000	7,456	9,613	9,843
96,000	9,236	11,103	11,299
97,000	11,185	12,689	12,845
98,000	13,298	14,368	14,478
99,000	15,571	16,139	16,197
100,000	17,999	17,999	18,000

Fig. 3. Impact on uncertain factors to WTA.

vessel. Therefore, the buyback price granted by the government should match the vessel owner's WTA. Otherwise the rate of participation in the program will be overestimated.

In addition to the profit uncertainty for vessel owners, the government should find out what are the reasons that cause this kind of uncertainty. If the government can restore steady profitability to vessel owners, there will be more incentives for those with lower waiting value to participate in the vessel buyback program. The intuition is that under the profit uncertainty faced by the fisheries industry, the first thing for the government to do is to stabilize the vessel owners' profit. If this is achievable, then the expected goals of the vessel buyback programs can be effectively reached. However, our data shows that the fisheries resources of offshore and coastal fisheries are steadily decreasing due to overfishing. To protect this trend from worsening, Taiwan's Fisheries Administration has decided to implement the vessel buyback programs continuously in following years, and to increase the price of purchased vessels from 40% up to 270%. This confirms our model's implications. Moreover, we have been informed that the expense of brought trawl equipments this year will be subsidized. This implies that the waiting value has been increased tremendously. It is suggested that the government has to increase the vessel buyback price to make vessel owners having higher incentives to give up their aged vessels.

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