Participation in Vessel Buyback Programs: An Option Value Model of the Vessel-Scraping Decision

Chung, Ching-Ta, Yao-Hsien Lee and Chin-Chen Chen*
vessel retirement policy in experimental analysis as well as the discussion of theoretical model.

This paper applies a Real Option Model which has been developed by Dixit (1993), Dixit and Pindyck (1994), Trigeorgis (1999), and Moretto (2000), setting up a stochastic model of vessel retirement policy, also affected the retirement policy from the owners under taking into consideration for the uncertainty of waiting value. At the same time, it also led the boat owners to accept the Willingness-to-accept (WTA) amount of buyback aged vessel program, and explained the reason why the plan of buyback aged fishing vessels from government cannot be accomplish effectively, maybe because the uncertain fishing net profit caused the waiting value, which made the owners postpone their willingness of retired aged vessels. The structure is set up as follows: next section develops a stochastic policy model of retirement aged vessels and the analysis of the retirement policy from the boat owners as well as the impact factor, such as waiting value of vessel owners and vessel purchasing price of WTA, and the amount of buyback aged vessels from government are derived in section III; Section IV is numerical simulation analysis and conclusion in the final section.

II. The Buyback Program in Taiwan

Background

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 base year, respectively. Technological improvement in engine design causes the total horse power to rise sharply. The discrepancy in growth rate between number of boats and tonnage implies that larger vessels made of steel are replacing wooden vessels in recent years. The stimulation policy adopted by the Taiwan government greatly increased fish landing till the late 70s. The recent trend in landing seems to suggest that growth of the fishery industry may have begun to exert pressure on fish stocks.

![Figure 1. Capacity Growth of Taiwan Fishing Industry](image)

In response to 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, decreasing profits had turned many fishing vessels to smuggling and other illegal activities which the program was expected to curtail. Second, the buyback program in its second year targeted high seas drift net vessels to comply with the UN resolution banning their use\(^3\). Third, the buyback program was expected to accelerate the salvage of old

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\(^1\) 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 stimulated the industrial capacity.

\(^2\) 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.
boats and reduce congestion and 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 inform the fishermen. Applicants were then required to register at the fishery department of county authority. Application was then submitted to the Council of Agriculture for approval. However, no historical catch records or revenues were used for screening. The approved vessels along with their licenses were turned over to the local government. They were then scrapped; the ones made of woods were burned and those made of steel or FRP were submerged to form artificial reefs. Details of operational procedures for the buyback program as follows (Figure 2):

![Figure 2 Operational Procedures of the Buyback Program](image)

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 boats 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 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 use. In 1993, priorities were assigned to assure that active boats 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 anymore. Similar schemes were also adopted in 1994.

**Program Results and Its Impact on Resource Conservation**

Taiwan government spent SNT 1.873 billion of a total of 3 billion budget to implement the five years program. Ninety one percent of the total spent money was used to purchase vessels, about 8% on deactivating the purchased vessels and 1% on administration management. Tables 1 to 4 summarize the total number and percentage of boats bought in each key administrative region broken down by year, type of boat, vessel age, and fishing categories. Table 1 shows that the majority of the vessels were bought back in the first three years. The rate of program prosecuted varies significantly over geographic regions as shown by the Chi-square test. Because the program targeted aged vessels, about 90% of vessels bought back were 15 years old or older except in Keelung where 40% of the boats were between 12 and 15 years old (Table 2). In terms of body type, the majority of vessels were wooden because of their low salvage value (Table 3). The total number of boats reclaimed was 2,337 equivalent to about 15 percent of the total number of powered vessels in 1990 before the program started. Table 4 shows that number of vessels bought are similar between net fishery and line fishery while net fishery has more tonnage than line fishery. Trawl net and long line are major two fishing categories participating in this buyback program. According to Taiwan Fisheries Bureau, reclaimed parking space for vessels in fishing harbors are estimated 119,983 square meters. Among total buyback vessels, there were 340 vessels (335 of total 461 buyback steel vessels and 5 of total 9 buyback FRP vessels) weight total 60,170.4 tons submerged in 14 regions as artificial reef, which estimated provide 60 thousand cubic meter fishing ground.

**Table 1. Aggregate Number and Percentage of Vessels Bought Back**

<table>
<thead>
<tr>
<th>County Name</th>
<th>Number Reclaimed</th>
<th>Percent of Total Industry Fleet Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keelung</td>
<td>66</td>
<td>29</td>
</tr>
<tr>
<td>Ilan</td>
<td>170</td>
<td>87</td>
</tr>
<tr>
<td>Taipei</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Kaohsiung Hsien</td>
<td>26</td>
<td>33</td>
</tr>
<tr>
<td>Pingtung</td>
<td>71</td>
<td>74</td>
</tr>
<tr>
<td>Penghu</td>
<td>230</td>
<td>132</td>
</tr>
</tbody>
</table>

**THEME H: Future Paths for Rights Based Fisheries Management**

**Participation in Vessel Buyback Programs: An Option Value Model of the Vessel-Scraping Decision**
Kaohsiung City 197 169 181 60 38 6.05 5.60 6.53 2.33 1.52
Other 77 54 34 52 14 5.67 4.36 3.04 4.79 1.18
Total 874 614 527 211 96 5.57 4.17 3.69 1.59 0.72

Chi-Square * 113.50 48.77 180.93 202.69 66.86


Note: *Chi-square statistic for testing null hypothesis that all eight counties number of vessel purchased is jointly equal.

Table 2. Number of Vessels Bought by Vessel Age

<table>
<thead>
<tr>
<th>County Name</th>
<th>Number of Boats</th>
<th>Percentage of Total Reclaimed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age&gt;20</td>
<td>15&lt;Age&lt;20</td>
</tr>
<tr>
<td>Keelung</td>
<td>55</td>
<td>107</td>
</tr>
<tr>
<td>Ilan</td>
<td>203</td>
<td>125</td>
</tr>
<tr>
<td>Taipei</td>
<td>63</td>
<td>36</td>
</tr>
<tr>
<td>Kaohsiung Hsien</td>
<td>62</td>
<td>21</td>
</tr>
<tr>
<td>Pingtung</td>
<td>106</td>
<td>77</td>
</tr>
<tr>
<td>Penghu</td>
<td>312</td>
<td>104</td>
</tr>
<tr>
<td>Kaohsiung City</td>
<td>330</td>
<td>242</td>
</tr>
<tr>
<td>Other</td>
<td>144</td>
<td>88</td>
</tr>
<tr>
<td>Total</td>
<td>1275</td>
<td>800</td>
</tr>
</tbody>
</table>


Table 3. Number and Percentage of Vessels Bought Back by Body Type

<table>
<thead>
<tr>
<th>County Name</th>
<th>Number of Boats</th>
<th>Tonnage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wooden</td>
<td>Steel</td>
<td>FRP</td>
</tr>
<tr>
<td>Keelung</td>
<td>75</td>
<td>183</td>
<td>2</td>
</tr>
<tr>
<td>Ilan</td>
<td>335</td>
<td>38</td>
<td>1</td>
</tr>
<tr>
<td>Taipei</td>
<td>105</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Kaohsiung Hsien</td>
<td>86</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pingtung</td>
<td>184</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Penghu</td>
<td>416</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Kaohsiung City</td>
<td>424</td>
<td>220</td>
<td>1</td>
</tr>
</tbody>
</table>

Application in vessel buyback programs is usually voluntary, vessel owners 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 selling the vessel is simply the profit that could have been realized if the vessel continues its fishing operation. For a rational individual, the comparison of the opportunity cost and the program benefit determines the decision. 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. The vessel buyback program of Taiwan was well funded and the program had opportunities for revision and improvement during its five-year run. In this study, we examine 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 respondents think that the buyback scheme is reasonable. Referring to Table 5, the minimal price acceptable for the vessel buyback program is NT$12,000 which was designed by government. Following the introduction of this buyback program, a market for such vessel trade is created since the total tonnage is limited and new entry is prohibited in 1989 unless permit transfer from old vessel. The highest price is for line fishery vessel between 10-20 tonnage, average NT$28,5000, vessels of this category are sold to be market for recreational fishing vessels. However, the lowest price is for net fishery vessel between 0-5 tonnage, average NT$16,750, vessels of this category are heavily trade in the market. The overall average acceptable incentive for applying in the vessel buyback program is NT$24,375 which is well above the NT$12,000 buyback price.

<table>
<thead>
<tr>
<th>District</th>
<th>Total Net Fishery</th>
<th>Total Trawl Net</th>
<th>Total Line Fishery</th>
<th>Total Long Line</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keelung</td>
<td>260 21932.7</td>
<td>223 21034.3</td>
<td>184 20557.4</td>
<td>36 889.1</td>
<td>33 868.9</td>
</tr>
<tr>
<td>Tainan</td>
<td>374 9454.6</td>
<td>55 4104.3</td>
<td>45 3561.9</td>
<td>285 4923.3</td>
<td>274 4771.6</td>
</tr>
<tr>
<td>Kaohsiung</td>
<td>114 1934.9</td>
<td>68 1217.8</td>
<td>5 490.7</td>
<td>41 682.4</td>
<td>41 682.4</td>
</tr>
<tr>
<td>Pingtung</td>
<td>86 1226.0</td>
<td>48 662.5</td>
<td>15 166.6</td>
<td>38 563.5</td>
<td>38 563.5</td>
</tr>
<tr>
<td>Penghu</td>
<td>184 2582.2</td>
<td>28 504.6</td>
<td>14 220.0</td>
<td>156 2077.7</td>
<td>145 1995.7</td>
</tr>
<tr>
<td>Kaohsiung City</td>
<td>428 9690.2</td>
<td>359 5668.0</td>
<td>83 2561.3</td>
<td>68 3996.6</td>
<td>68 3996.6</td>
</tr>
<tr>
<td>Others</td>
<td>246 3769.6</td>
<td>158 2647.9</td>
<td>29 777.8</td>
<td>70 931.4</td>
<td>63 901.9</td>
</tr>
<tr>
<td>Total</td>
<td>2337118354.4</td>
<td>115567764.2</td>
<td>567 59431.3</td>
<td>112349902.4</td>
<td>108747660.6</td>
</tr>
</tbody>
</table>

the following second order dif
Following is to select a threshold value \( b \) to maximize the equation (2). ………

Now, those factors all influence the owners’ profit value in the period of owing fishing fleet for owners will be

\[
F(t) = \int_{0}^{t} \int_{0}^{t} C e^{\alpha s} ds \int_{s}^{t} e^{\beta y} dy, \quad t \geq 0
\]

The frontier condition is \( F(t) = 0 \), and the general solution is
\[ F(\square) = G\square^2 + D\square + \frac{\square}{r\square} \]  
(4)

where, \( \square_1 > 0, \square_2 < 0 \) are roots of Brown’s fundamental quadratic

\[ \square(\square) = \frac{1}{2}\square^2 \square(\square + 1) + \square r = 0 \]  
(5)

In order to make \( F(\square) \) has the fixed estimated value when \( \square \) is approaching to the maximum value, \( G\square^2 \) must be zero. In equation (4), \( \frac{\square}{r\square} \) is the net present profit value of owner to keep a vessel; \( D\square \) represents the net profit of cycling purchase vessel and must be positive value. In order to determine the lowest value of constant \( D \) and net profit, we have to consider the following conditions such as

(a) Value matching condition:  
\[ F(b) = F(m)\square C, \text{ and} \]
(b) Smooth pasting condition:  
\[ F(b) = 0 \]

The value matching conditions are indicated in switching the period of new and old fishing fleets, the owners will have the same evaluation to either old or new vessels when they faced the decision making in the suitable retirement conditions. In addition, it needs to meet the first order condition of equation (2), and thus following two equations need to be solved:

\[ D(b^*; m) = \frac{m \square b}{r \square} \square C \]  
(6)

\[ D(m; b) + \frac{b}{r \square} = 0 \]  
(7)

Since \( \frac{b}{r \square} > 0 \), \( D>0 \) is required to satisfy equation (7). Based on this result and the condition of \( m>b \), we obtain

\( m \square C(\square) > b \). Assume \( b^* = m \square C\square \), here \( b^* \) value means under the certainty of net profit, the net value occurred form purchasing a new vessel, i.e. the net profit minus the opportunity cost \( C(\square) \) of investment; it is clear that under the certainty of net profit, if the net profit \( \square \) of vessel reaches the value of \( b^* \), boat owner will purchase new vessel. However, if the net profit is uncertain, then we have \( b^*>b \). In other words, under the conditions of net profit uncertainty, whether vessel owners want to purchase the new vessels, it will depend on the net profit \( \square \) if it has reached to the value of \( b \). Therefore, under the conditions of net profit uncertainty, vessel owners will wait for obtaining much more information about aged vessel net profit before they decide to purchase any new vessels; then they will make a decision policy to buy the new ones.

That is because the policy norm is the value of \( b \) instead of the value of \( b^* \), which means the waiting value is \( W = b^* \square b = m \square C(\square) \square b \). Obviously, the waiting value for owners comes from the parameter value in the model under the conditions of net profit uncertainty.

IV. 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 boat owners still own their vessels. Here, we use \( F(b) \) which represents the owner’s expected net present profit value of giving up aged vessel, while \( F(\square) \) is owner’s current net present profit value and \( \square [b, \square] \). Therefore, in order to induce owners who have got the net profit up to \( \square [b, m] \) to accept the aged vessel buyback program offered by the government, trying not to wait for the net profit \( \square \) up to the value of \( b \), then accepting the buyback aged vessels program from the government so the amount of buyback \( R \) must.

\[ F(b) + R = F(\square), \text{ or } R \geq F(\square) - F(b) = U(\square, b) \]  
(8)
In equation (8), \( U(J, b) \) is the WTA for owner to accept the government buy-back program, and this WTA is related to exist vessel’s net profit \( J \), uncertain degree of net profit \( J \), new vessel’s purchasing cost \( C \), discount rate \( r \), and the trend value of \( J \). Through calculation, equation (8) can be rewritten as

\[
U(J, b) = D(J^{[\frac{\partial}{\partial J}]} b^{[\frac{\partial}{\partial J}]} ) + \frac{1}{r} \int \frac{J}{b} \frac{J}{b} \]  \hspace{1cm} (9)

From the observation the equation (9), we can know when the fishing fleet net profit reach to the value of \( b \), \( U(b, b) = 0 \); at that time, only if the buyback amount offered by government, the fishing fleet owners are sure to give up their aged vessels. As a matter of fact, even if the vessel owners have not accepted the conditions of buyback aged vessels plan, they will be making a decision to buy new fishing fleets. On the other hand, if the fishing craft is new or the external factor such as smuggling activities or selling the fishing fleet oil, will cause the net profit to be \( J = m \), and then \( U(m, b) = C \). Meanwhile, we also see when \( \frac{J}{b} = 0 \), that is the fishing fleet net profit is under certain situation, we can revise WTA as follows:

\[
U(J^{*}, b^{*}) = \frac{1}{r} \int \frac{J}{b} \frac{J}{b} \]  \hspace{1cm} (10)

and

\[
U(m^{*}, b^{*}) = 0 \Rightarrow C = U(m, b) = C \]  \hspace{1cm} (11)

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

(1) By the impact of net profit uncertainty, the ship owners are getting more interested in taking part in buyback aged vessel program from their WTA because of \( U(J, b) > U(J^{*}, b^{*}) \), which forced their willingness to replace new fishing fleets in a slow pace so that the aged vessel program from the government is hard to achieve the expected effects.

(2) The buyback amount of aged vessel from the government should be between \( [0, C] \). And we are sure that the amount is related to the net profit level \( J \), for ship owners in the time period of \( t \).

V. Numerical Simulation

For the purpose of analyzing how the net profit uncertainty affect the WTA, we can assume three uncertain factors \( \frac{J}{b} = \) (net profit is certain), \( \frac{J}{b} = 1 \) and \( \frac{J}{b} = 10 \); \( r = 0.05 \), \( \frac{J}{b} = -0.5 \), \( C = 100,000 \), then use equations (5), (6) and (7), we can get value of \( \frac{J}{b} , D \) and \( b \). Finally, substitute these value into equation (9), we obtain the relative equations (12), (13) and (14) of WTA and net profit.

1. when \( \frac{J}{b} = 0 \), we have \( \frac{J}{b} = -1 \), \( D J 74,967,890,560 \), \( b J 86,584 \)

\[
U(J, 86584) = 74967890560(J^{[\frac{\partial}{\partial J}]} 86584^{[\frac{\partial}{\partial J}]} ) + 10(J^{[\frac{\partial}{\partial J}]} 86584) \]

\[
U(J, 82296) = 25345114(J^{[\frac{\partial}{\partial J}]} 86584^{[\frac{\partial}{\partial J}]} ) + 10(J^{[\frac{\partial}{\partial J}]} 82296) \]

\[
U(J, 81645) = 825736578(J^{[\frac{\partial}{\partial J}]} 81645^{[\frac{\partial}{\partial J}]} ) + 10(J^{[\frac{\partial}{\partial J}]} 81645) \]

(12)

(13)

(14)
Figure 3  Impact on Uncertain Factors to WTA

VI. Conclusion

Based on the analysis from this paper, under the net profit uncertainty of ship owners, the ship owners would put off their decision of taking part in vessel buyback program. As a result, when the government makes a decision in the amount of buyback program, it should consider not only the operation year for fishing fleets, but also the managing situation variance of ship owners. For example, the ship owners’ net profit level is also the same as the capability of making a profit and situation for aged vessels, which shows the residue of aged vessels and the investment cost for fishing fleets. Under those circumstances, the buyback amount from the government should match the ship owners’ WTA.

In addition to the net profit uncertainty for ship owners, the government should find out what are the reasons that cause this kind of uncertainty situation. If the government can hold steady net profit for ship owners, then they will have more lure motive as well as the lower waiting value to join the buyback vessels policy from the government. Therefore, when facing the uncertain situation in running their industry, the first thing to do is to stabilize the ship owners’ net profit, then to carry out the plan of buyback fishing fleets so that it can be reached the established goal in this buyback project effectively. According to the data, it shows that the fisheries resources of offshore and coastal fisheries are decreasing much less, so Fisheries Administration decided to take effect on buyback aged vessels continuously in following years, and increasing the price of buyback vessels up to 40% - 270%. Moreover, the expense of buyback trawl equipment this year will be additionally subsidized. In this case, it will show that the waiting value has been increased tremendously under net profit uncertainty, so that the government will have to increase the payback price to make ship owners have the lure motive to give up their aged vessels.

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