A STOCHASTIC INVESTMENT MODEL FOR A SURVIVAL CONSCIOUS FISHING FIRM

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SUMMARY AND CONCLUSIONS

The purpose of this study was to develop further mathematical aids for investment-financial decision making in shrimp fishing. The model developed allows for random prices and catches per vessel and, in addition, takes into account all of the information known to the decision maker at each time of decision. Survival of the fishing firm is regarded as a fundamental factor influencing the firm's investment decisions.

In making each decision, the fisherman evaluates the firm's net equity position, the worst possible sequence of revenues that might materialize, and all of the firm's forthcoming obligations. He derives from this information a survivable set of capacity purchases, and then selects from this set the investment maximizing his net worth at the end of the planning period. After each year's operations and before the next year begins, the random revenue variable for the first year has been observed. It is now a part of the information for decision making in the second year. The fisherman repeats the above reasoning process in making his investment decision for the second year, and in every year thereafter. Survival must be guaranteed before any investment is undertaken; moreover, investment decisions are always conditioned by experience.

In accordance with information obtained from cooperating firms, values for all of the parameters were specified. Initially, the firm was assumed to have had purchased one new 73 foot steel hull vessel, or to have the money equivalent in savings. To reflect inflation, prices were assumed to increase 3 percent per year. For tax purposes, the depreciation period was 11 years, and the income tax rate was 25 percent. The length of the planning period was taken to be 5 years.

Since the shrimp price is highly influenced by the rate of growth in per capita income, expected prices for the years 1970 through 1974 were projected for a modest rate of economic growth (as observed in the late 1950's) and for a high rate of economic growth (as observed in the mid 1960's). Investment solutions were calculated for both growth rates. The marginal value of another vessel was found to be initially larger and to be positive for a longer period of years at the high growth rate than at the lower. Success in shrimp fishing is clearly influenced by the rate of income growth in the economy.

The value of better than average management was also clearly illustrated. Almost six more vessels were purchased than in the case of average management.

In evaluating the rate of return over cost from fishing in relation to the savings alternative, investments in fishing capacity were found to be a better alternative than savings as long as the interest rate was less than 9.5 percent per year. Then a switch occurred in favor of the savings alternative. Thus, given the present borrowing rates, investments in fishing capacity are near the margin of profitability (in a survival sense), as far as interest rates are concerned.

Solutions were calculated for the case where price was random as well as landings. Only slight differences were found between the results in the two sets of problems. Vagrancies in landings per vessel seem to be much more important than unexpected variations in price.

A Stochastic Investment Model for a Survival Conscious Fishing Firm

by

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1. Introduction

In 1969, Thompson and George [2] formulated a stochastic dynamic investment model for the survival conscious firm, derived the optimal decision rules for investment, and computed solutions to several problems. This model takes into account the probability distribution of the yield (catch) and output price, as well as all of the information known to the decision maker at the time of each investment decision. The entrepreneur is assumed to be initially in a financial position so that a feasible investment solution always exists if the lowest output price and yield occur in every period of the planning horizon. In the model, the objective of the firm is to maximize expected net worth at the end of the planning horizon. Of course, all production expenses, investment outlays, interest costs, and planned cash withdrawals must be paid for as incurred (or scheduled).

Because of the vagrancies of fish prices and catches this model would be expected to be a particularly appropriate decision aid for investments in fishing capacity. There are generally few, if any, alternative uses for specialized fishing equipment. Also, fishermen typically have poor alternative opportunities by which to earn a living. Low prices and small catches would be expected, as a result, to be dreaded much more than high prices and large

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catches are desired. A sequence of worse than expected net revenues (even in the case of a very favorable expectation) could terminate the existence of the fishing firm. This could well be an unacceptable risk of failure. Hence, survival of the fishing firm would be expected to be fundamental factor influencing the firm's investment decisions.

2. Development of the Survival Model

In the survival model, the fisherman evaluates the worst sequence of net revenues that could occur in every year of the decision-making period. This sequence, in conjunction with the value of the initial investment in fishing capacity and the position of the money account, determine the survivable set of fishing capacity purchases at the beginning of the first year. The fisherman selects from this set the investment that contributes the most to his terminal net worth. After the first year and before the second fishing year begins, the fish price received and the catch landed in the first year have been observed. This is now a part of the information known to the fisherman for planning in the second year. The fisherman again evaluates the worst sequence of catches and prices that could occur in every remaining year of the decision-making period. This abbreviated sequence is now evaluated in conjunction with the capacity and money position at the end of the first year. It determines the survivable set of capacity purchases for the second year. Again, as in the first year, the fisherman selects from this second set the investment that contributes the most to his terminal net worth. This procedure is repeated in every year throughout the decision-making period. Investment decisions are conditioned by experience, and are not based solely on expected values.

We simply say that a fishing firm survives in a given year if the value of the fishing capacity exceeds the value of the indebtedness. A survivable investment is defined in the following setting: the fisherman has completed the fishing season in year k-1 and is now planning for year k. He wants to survive above all else during the remaining N - (k-1) years of the decision period, even if all future catches and prices are the lowest possible. An investment decision in the k^{th} year, a_k, is said to be survivable if the value of the fishing capacity in every remaining year is never less than the indebtedness owed (with fishing capacity not being purchased in any of the years after the k^{th} one and the lowest net revenues being visualized in every year of the yet undisclosed future).

Under these conditions, a survivable capacity purchase in year k is found to be equivalent to the following one: the product of the capacity units purchased in year k and the marginal value of fishing capacity calculated under the assumption of the lowest net revenue occurring in every forthcoming year--the marginal cost of fishing capacity visualizing the worst--is never greater than the value of the fisherman's money account in year k-1 plus the terminal value of the capacity owned in year k-1 minus the losses from utilizing the present fishing capacity in all of the remaining years (with the lowest prices and smallest catches occurring) minus the fixed cash withdrawals in the rest of the planning period. (All money flows are adjusted for the values of alternative opportunities, income taxes, and depreciation.) This upper-bound would be the value of the fisherman's assets if the worst possible sequence of net revenues occurred--the fisherman's final asset position visualizing the worst.

To reflect the fear of low net revenues when the lowest price and catch occurs, revenue per unit of fishing capacity is assumed to be less than operating cost per unit of fishing capacity. It is also assumed that per unit prices of fishing capacity are not increasing so rapidly that operating losses per unit may be covered by value appreciation in fishing capacity. (Speculation is never a sure bet.) This implies that the marginal cost of fishing capacity visualizing the worst is positive. Hence, dividing the lower bound for the fisherman's final asset position by this positive marginal cost, the upper-bound for a survivable purchase of fishing capacity in a given year is obtained. This represents the maximum amount of fishing capacity that the fisherman can purchase and still insure survival of the firm throughout the rest of the decision period. It depends upon the value of the firm's money account, the amount of capacity owned, and the value of that capacity in the previous year. This upper-bound function in year k is denoted by $H_k(Z_{k-1}, y_{k-1}, x_{k-1})$, where at the end of the k-1st year Z_{k-1} is the cash balance, y_{k-1} is the units of fishing capacity owned and x_{k-1} is the purchase value of the firm's capacity. The firm is in debt if Z_{k-1} is negative and has savings if Z_{k-1} is positive.

We will also introduce the following notation now: s_i is the units of fishing capacity purchased at the beginning of the ith year (and used for the first time in year i); τ_i is the operating costs per unit of fishing capacity in year i; σ_i is the per unit purchase price of fishing capacity before the beginning of the fishing season in year i; Δ_i is the fixed cash withdrawal in year i for scheduled expenses independent of fishing operations and investments in fishing capacity per se; γ is the interest rate paid (or received) on the cash account Z; ω_i is the unknown revenue per unit of fishing capacity in the i^{th} year: N is the number of years in the planning period; β is the fraction of the value of the fishing capacity recoverable at the end of the planning period; δ is the income tax rate; and ϵ is the straight-line depreciation fraction. Also E will be used to denote the mean of the random variable ω_i; and L will be used to denote the smallest possible annual net revenue having a positive probability of occurring.

Using the above development, the survival model may be stated as follows:

Maximize $E(Z_N + \beta\sigma_{N+1}y_N)$ over all n-tuples of functions $s_i(\omega_1,\omega_2,\ldots,\omega_{i-1})$, $i = 1,2,\ldots,N$, satisfying the difference equations

$$x_i - x_{i-1} = \sigma_i s_i, \; x_o = \sigma_o y_o,$$

$$y_i - y_{i-1} = s_i, y_o \text{ given and non-negative},$$

$$Z_i - Z_{i-1} = \gamma Z_{i-1} + y_i(\omega_i - \tau_i) - \sigma_i s_i - \Delta_i - \delta\, [y_i(\omega_i - \tau_i) + \gamma Z_{i-1} - \epsilon(x_{i-1} + \sigma_i s_i)], \qquad \epsilon = .091,$$

$i = 1, 2, \ldots, N$, and satisfying the inequalities

$$0 \leq s_i \leq H_i(Z_{i-1}, y_{i-1}, x_{i-1}), \; i = 1, 2, \ldots, N.$$

In words, the model fisherman desires to maximize expected net worth at the end of the decision period where the purchases of capacity are selected from the survivable set in each year (delineated by the inequality restrictions). Thus, in the maximization process, the model fisherman, who takes into account all of the information known at the time of decision, selects the investment from the survivable set of capacity purchases that maximizes expected net worth at the end of the planning horizon.

3. The Decision Rule for Investment

By the use of dynamic programming methods, we extended the method developed by Thompson and George [2] to allow for depreciation and income taxes. The extended rule for optimal investments is summarized in the following theorem.

<u>Theorem</u>: Suppose $H_1(Z_o, y_o, x_o) \geq 0$, i.e. the upper-bound for investments in the first year is non-negative. Let R_k be the expected marginal value of fishing capacity for survival investment decisions--the marginal value of fishing capacity visualizing the worst. Then the decision rule for optimal survivable investment is as follows:

$$s_k^o = H_k(Z_{k-1}^o, y_{k-1}^o, x_{k-1}^o) \text{ if } R_k > 0, \text{ and } s_k^o = 0 \text{ if } R_k < 0 \text{ with the}$$

feasible value of s_k being immaterial if $R_k = 0$.

In other words, the fisherman buys the survivable limit of fishing capacity in year k if the marginal value of fishing capacity visualizing the worst is positive in that year, and he doesn't buy anything if this marginal value is negative. It also follows that the optimal purchase is immaterial in any year (because of the linearity of the problem) whenever the decision rule is zero. The upper bound for investments in the first year insures the existence of a feasible investment solution in each year of the planning horizon.

4. An Application to Shrimp Fishing

To indicate how the model may be applied to a shrimp fishing firm, parameters were specified for a relatively small fishing firm operating 73 foot steel hull trawlers (see Table 1, p. 16). In the specifications, the values of the parameters were specified to reflect prices, costs, and landings per vessel as reported by the firms cooperating in the study. There is an exception with regard to Problem 4. Average landings per vessel were specified to be one standard deviation above the mean to indicate the effect of better than average management.

Since the real price of shrimp -- the price adjusted for the purchasing power of money -- is highly influenced by growth in per capita income (real), and since it appears that the economy may be entering a period of modest growth (possibly much like the late 1950's), the real price of shrimp was specified to reflect a 1.5 percent rate of growth in per capita income in Problems 1, 2, and 3, and to reflect a 3.3 percent rate of growth (as observed in the mid 1960's) in Problem 4.

To evaluate the economic attractiveness of shrimp fishing versus the best alternative to fishing (as reflected by the interest rate on money), the decision maker in Problem 2 initially has the money equivalent of an investment in one vessel. Recall that the entrepreneur is a profit maximizer, given that he can survive. Thus, the decision maker would opt for the savings alternative whenever the net rate of return from a dollar invested in fishing capacity is less than the interest rate on money. That is, the second problem indicates the economic advantage (or disadvantage) of investing in fishing relative to loaning the money to someone else.

Since the model takes into account the information obtained through time as the values of the random variables are revealed, solutions to two sets of problems were computed. In the first set, the landing per vessel is random; whereas in the second set, the price received is random as well. The first set of results is presented in Table 2, p. 17, and the second set in Table 3, p. 18.

It is important to note that this application of the survival model is not exhuastive of the many that could be made, or to imply that the normative results presented are likely to occur. This work is only meant to indicate how an investor interested in shrimp fishing, who has a limited amount of money capital, might obtain bench marks (from the model) for investment planning.

Initial values for the difference equations and values of the parameters.

In this application, the value of y_o -- the initial amount of fishing capacity -- is specified to be one 73 foot steel hull trawler in Problems 1, 3 and 4. This type of vessel fully outfitted for shrimp fishing costs $100,000 at the beginning of 1970. To reflect inflation, the purchase price of the new vessels was specified to increase at 3 percent per year.

In recent years, there have been steady improvements in technology with newer vessels being powered by more horsepower. Thus larger trawls could be pulled at a faster rate. This rate of technological improvement was assumed to have increased costs by 2 percent per year.

From the cost records of the cooperating firms, the annual cost of operating a 73 foot trawler was found to be $30,000 in 1969. This cost figure includes an allowance for overhead and insurance costs. Representatives of the firms interviewed indicated these costs have increased by 3 percent per year in recent years. Thus, the annual production cost[1] per vessel, τ_t, was specified to be 30,000 $(1.03)^t$.

Straight line depreciation methods were used for tax purposes with an 11 year depreciation period being used for a fully outfitted vessel. This average was estimated on a value weighted basis from the records of a number of firms. The reciporical of this figure, .091, was the depreciation fraction used for the value of ϵ.

Income for tax purposes is the sum of the revenue received by the owner after the "lay" less operating costs, interest costs, and depreciation. The income tax rate, which is denoted by δ, was taken to be 25 percent of this figure. This rate was paid in the late 1960's by a number of the small fishing firms studied.

In shrimp fishing, as in every business, there are sundry expenses for a number of factors related to the firm. Some of these costs, it might be argued, are not absolutely necessary for the operation of the business; but for the sake of convenience (or acceptance), they are commonly incurred. Such costs are difficult to estimate. Thus, in this study, a base allowance of $3600 per year was specified for sundry expenses.

In shrimp fishing, the captain and first mate of the vessel are commonly paid on a "lay" basis wherein they receive an agreed upon percentage of the revenue earned by the vessel. The third crew member, who is called a header, is typically paid on a per box basis. An allowance for his wages was included in the value of the production cost per vessel. For vessels of the type being considered, the "lay" for the captain and first mate is commonly 35 percent[2] (who typically pay for all of the groceries).

In interviewing the cooperating firms, the relative resale value of the vessels sold was found to be fairly well approximated for vessels five to six years old by summing the accumulated depreciation fractions with an appropriate adjustment for technological improvement. This procedure using the largest possible technology factor[3] gave a 0.65 value for β;

$(.091)\, 5 + [(1.02)^5 - 1]$.

In the specification of the owner's expected annual revenue per vessel, E_t, the log of the real shrimp price received by the cooperating firms, p_t, was regressed on the log of the index of real per capita income, y_t, and the log of the per unit effort landings, l_t, (caught in depths beyond 10 fathoms off the Texas coast), as reported in the earlier study by Thompson et al. [3, p. 12]. The resulting estimated regression equation was:

$$\ln p_t = -4.571 + \underset{(t=3.6)}{1.175 \ln y_t} \underset{(t=3.5)}{- .379 \ln l_t}. \quad R^2 = .748, \quad \sigma e = .0888$$

Variations in landings for a given fishery (like the one off the Texas coast) are still regarded by biologists as being largely random . Thus to remove the effect of landings on price, landings were specified to be equal to the mean value observed for the Texas fishery in the period 1958 through 1967. Hence, the price estimating equation (with base year 1969) was:

$$\ln p_t = -1.332 + 1.175 \ln y_t.$$

To use this equation, it was necessary to project the index of real income per capita for the five years 1970 through 1974. This was done by regressing $\ln y_t$ on time , t, for the years 1953 through 1960, and also for the years 1961 through 1968. The following two income projection equations were developed for the period t = 1970, ..., 1974.

Specification I: 1.5% rate of growth in real per capita income

$$\ln y_t = 4.94 + .015t$$

Specification II: 3.3% rate of growth in real per capita income

$$\ln y_t = 4.94 + .033t$$

To convert to money terms, the projected prices from these equations were multiplied by the value of the consumer price index (with base 1957/59 = 100) for 1969, 1.277, and by a price inflating factor of 3 percent in each year thereafter. Taking the product of the projected price and the expected annual landing per vessel with an adjustment for the lay fraction, the owner's expected annual revenue per vessel was obtained. The expected annual landing per vessel used in this study was the average of the landings per vessel obtained by the cooperating firms in the period 1958 through 1969(57,560 pounds of heads off shrimp).There was, of course, a steady rate of technological improvement in that period so that this average is likely to be an underestimate of a 73 foot vessel's annual catch potential. Thus, the value of the expected annual owner's revenue per vessel for each stipulated economic growth rate, E_t, is a more conservative estimate than possibly is the case, it might have been further increased for expected technological improvements.

For the first set of four problems, the estimate of the owner's lowest annual revenue per vessel, L_t, was found by taking the lay residual of the product of the 1969 shrimp price and the projected lower bound for landing per vessel. This lower bound was taken to be 3.4 standard deviations (in t units for 11 degrees of freedom) below the mean landing per vessel of 57,560 pounds with the sample standard deviation being 5,731 pounds. Thus,the probability of the landing per vessel being greater than this lower bound (assuming this to be a valid probability basis) is greater than .99. Moreover, since the growth rate in real per capita income was implicitly taken to be zero, the probability of revenue per vessel falling below the implied estimate of the owner's lowest annual revenue per vessel (where the price is projected under either specification) decreases steadily as the planning period unfolds. In other words, the estimate of L_t is very conservative for the year 1970 and becomes increasingly conservative thereafter in the planning period.[4]

For the second set of two problems in which the shrimp price is random as well as the landing per vessel, the same value was used for the owner's lowest annual revenue per vessel. This resulted in a slightly smaller probability of survival than in the first four problems (because of the additional randomness in the price), but one still greater than .99. Thus, in the interest of simplicity, the same value of L_t was used in both sets of problems.

Knowledgeable industry representatives (who were consulted with regard to the above specifications) indicated a five year survival period would be especially meaningful for firms operating the 73 foot trawlers. Accordingly, two five year sequences of random revenues per vessel were developed with only the landing per vessel being random in the first sequence. Landings per vessel were regarded as independent of price, since the fishery has a relatively competitive structure; moreover, for the period studied, per vessel landings for the cooperating firms were not highly correlated with landings per unit of effort in the Texas fishery[5] ($r^2 = .16$). Using the regression estimate for price in each year 1970 through 1974 and the estimated standard error of the regression, and also using sample mean and standard deviation for landings per vessel of the cooperating firms, the random prices and landings per vessels were calculated as follows: (1) By use of the Box-Muller [1] method, normal random deviates for prices and landings per vessel were independently generated; and (2) the products of these two random variables were adjusted for the lay and changes in the purchasing power of money. The following random sequences were accordingly obtained and used in the analysis.

Random Sequences of Revenues per Vessel

Sequences No. 1

Problems 1 & 2	Problem 3	Problem 4
$30,741	$36,141	$31,413
42,572	48,233	44,457
39,859	45,795	42,531
39,797	46,020	43,393
50,784	57,308	56,583

Sequences No. 2

Problem 1	Problem 3
25,450	29,920
47,261	53,546
38,810	44,589
36,077	41,719
44,747	50,495

It may be helpful to recall that the decision maker is regarded as being a better than average manager in Problem 3. The 1.5 percent rate of real economic growth per capita is used in Problems 1, 2 and 3; and the 3.3 percent rate of economic growth is used in Problem 4.

In evaluating the solutions to the first set of four problems in Table 2, the results indicate the profitability of investing in shrimp fishing capacity during the 5 year planning period. The model fisherman opted for investing in fishing capacity in Problem 2, even though he had the option to leave his money in savings at 8.5 percent interest. Thus, the rate of return over cost from shrimp fishing was greater than 8.5 percent. In further analysis, it was found to continue to be until the rate of interest reached 9.5 percent; then the rate of return over cost switched in favor of savings.

The value of better than average management is indicated by the results in Problem 3. There, the average landing per vessel was taken to be one standard deviation (5,731 pounds) greater than in Problem 1. The same amount was invested in the first year; but in the second and third years there were striking differences. The model fisherman bought 5.8 vessels in Problem 2, while he did not buy any in Problem 1. He chose to pay off debt in the first problem after the initial investment, since that represented a more profitable use of his money. It may be noticed that the investment upper bound limited the size of the purchases in the first three years of Problem 3 (and the first year of Problem 1). The marginal value of another vessel was positive; however, the money was not available for investment (given the desire to survive).

Success in shrimp fishing is clearly influenced by the rate of income growth in the economy, compare Problems 1 and 4. In Problem 4, the marginal value of another vessel is almost twice as large in the first year as in Problem 1, and remains large in the second year when the value in the first problem goes negative. This increased growth in per capita income results in an increased ability to invest in the second year in Problem 4 and still further increased ability, at a lower marginal incentive, in the third year. The model fisherman carrys a considerably larger debt load, as a result of the increased profitableness, in Problem 4 than in Problem 1.

In evaluating the second set of results given in Table 3 and comparing these solutions to the ones in Table 2, only slight differences between the results may be noticed. Somewhat less is invested over the planning period in Problem 3 in the second case than in the first. Also, a slightly larger debt load was generally carried in most of the planning period.

The marginal investment incentives were, of course , the same in both sets of problems, they are based on expected values. Vagrancies in landings seem to be much more important than unexpected variations in price.

TABLE 1. Values of the Parameters for the Survival Problems

Parameters	Problems 1	2	3	4
N--number of years in planning period	5	5	5	5
Z_o--initial cash balance in dollars	0	96,145	0	0
y_o--initial number of boats in fleet	1	0	1	1
x_o--initial investment in dollars	100,000	0	100,000	100,000
γ--annual interest rate per dollar	.085	.085	.085	.085
τ_t--annual production cost per vessel in dollars	$30{,}000 \times (1.03)^t$	$30{,}000 \times (1.03)^t$	$30{,}000 \times (1.03)^t$	$30{,}000 \times (1.03)^t$
σ_t--per vessel purchase price in dollars	$100{,}000 \times (1.03)^t$	$100{,}000 \times (1.03)^t$	$100{,}000 \times (1.03)^t$	$100{,}000 \times (1.03)^t$
ϵ--annual depreciation fraction per dollar invested	.091	.091	.091	.091
ζ--annual income tax rate per dollar of taxable income	.25	.25	.25	.25
β--recoverable fraction of the investment in fishing capacity	.65	.65	.65	.65
Δ--annual cash withdrawal for sundry expenses in dollars	$3{,}600 \times (1.03)^t$	$3{,}600 \times (1.03)^t$	$3{,}600 \times (1.03)^t$	$3{,}600 \times (1.03)^t$
E_t--owner's expected annual revenue per vessel in dollars*	$49{,}790 \times \hat{p}_t(1.03)^t$	$49{,}790 \times \hat{p}_t(1.03)^t$	$54{,}400 \times \hat{p}_t(1.03)^t$	$49{,}790 \times \breve{p}_t(1.03)^t$
L_t--owner's lowest annual revenue per vessel in dollars	$22{,}500 \times (1.03)^t$	$22{,}500 \times (1.03)^t$	$22{,}500 \times (1.03)^t$	$22{,}500 \times (1.03)^t$

* See Appendix Table 5 for numbers used.

TABLE 2. Solutions to Four Survival Problems in Table 1, Landings Per Vessel are Random.

Problem	Year	Marginal Value of Another Vessel (dollars)	Investment in boats (number)	Boats Owned (number)	Cash Balance (dollars)	Debt to Gross Asset Ratio
	0	-	-	1.00	0	-
	1	5,843	1.44	2.44	-146,356	.57
1	2	-784	0	2.44	-127,678	.48
	3	-7,896	0	2.44	-116,862	.43
	4	-15,474	0	2.44	-108,022	.38
	5	-23,490	0	2.44	-74,436	.26
	0	-	-	0	96,145	-
	1	5,843	2.42	2.42	-145,083	.57
2	2	-784	0	2.42	-126,507	.48
	3	-7,896	0	2.42	-115,728	.43
	4	-15,474	0	2.42	-106,908	.38
	5	-23,490	0	2.42	-73,534	.26
	0	-	-	1.00	0	-
	1	21,419	1.44	2.44	-136,487	.53
3	2	16,198	1.13	3.57	-216,534	.56
	3	7,080	4.03	7.59	-581,958	.68
	4	-5,562	0	7.59	-511,662	.58
	5	-18,570	0	7.59	-358,977	.40
	0	-	-	1.00	0	-
	1	10,655	1.44	2.44	-145,128	.56
4	2	9,943	.80	3.23	-240,502	.58
	3	2,624	3.15	6.38	-503,596	.70
	4	-7,595	0	6.38	-462,898	.63
	5	-19,119	0	6.38	-341,999	.45

TABLE 3. Solutions to Two Survival Problems in Table 1, Shrimp Prices and Landings per Vessel are Random.

Problem	Year	Marginal Value of Another Vessel (dollars)	Investment in boats (number)	Boats Owned (number)	Cash Balance (dollars)	Debt to Gross Asset Ratio
	0	-	-	1.00	0	0
	1	5,843	1.44	2.44	-156,026	.60
	2	-781	0	2.44	-126,538	.48
1	3	-7,896	0	2.44	-118,206	.43
	4	-15,474	0	2.44	-118,517	.42
	5	-23,490	0	2.44	-100,311	.34
	0	-	-	1.00	0	--
	1	21,419	1.44	2.44	-147,856	.57
	2	16,198	.69	3.13	-176,191	.52
3	3	7,080	4.22	7.34	-569,170	.69
	4	-5,563	0	7.34	-533,307	.63
	5	-18,570	0	7.34	-438,263	.50

Footnotes

1. This cost figure is $4,000 higher in the base year than the one used by Thompson *et al.* [3].

2. In effect, the owner only gets 65 percent of the exvessel price.

3. This was done since the vintage was not kept track of in the model.

4. To have a probability support at L_t, it is being implicitly assumed that this small probability of non-survival is insurable. This point was pointed out by Robert R. Wilson.

5. Landings per unit effort in the Texas Fishery were highly correlated with landings per unit effort for the Gulf and South Atlantic.

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Appendix

Appendix Table 1. Values of Projected Index of Real Per Capita Income

Year	Specification I	Specification II
1	136.98	139.52
2	139.06	144.27
3	141.17	149.19
4	143.32	154.27
5	145.50	159.53

Appendix Table 2. Values of Projected Real Shrimp Prices

Year	Specification I, $\hat{p}_t$ (cents per pound)	Specification II, $\tilde{p}_t$ (cents per pound)
1	85.68	87.56
2	87.22	91.07
3	88.78	94.73
4	90.37	98.53
5	91.99	102.49

Appendix Table 3. Values of Landings per Vessel for Random Sequences 1 and 2

Year	Problems 1, 2 & 4 (pounds)	Problem 3 (pounds)
1	41,965	49,336
2	55,435	62,806
3	49,501	56,872
4	47,140	54,511
5	57,375	64,746

Appendix Table 4. Values of Real Shrimp Prices for Random Sequence 2

Year	Problems 1 & 3 (cents per pound)
1	70.93
2	96.82
3	86.44
4	81.92
5	81.05

Appendix Table 5. Values for Expected Revenues per Vessel

Year	Specification I (dollars per vessel per year)	Specification II (dollars per vessel per year)
1	42,231	43,154
2	44,277	46,234
3	46,421	49,533
4	48,670	53,068
5	51,028	56,855