NOTES

AN ECONOMETRIC ANALYSIS OF NET INVESTMENT IN GULF SHRIMP FISHING VESSELS[1]

The major capital inputs in the Gulf shrimp fishery are vessels and gear. Early vessels, built mostly of wood, employed drag seines, cast nets, and fixed traps to catch shrimp. Today, much larger and more powerful vessels, equipped with sophisticated fishing gear and accessories, trawl the Gulf of Mexico. The last 20 years has seen a remarkable substitution of steel and fiberglass vessels for wooden vessels. The factors underlying this aggregate investment trend in the Gulf of Mexico (hereafter referred as the Gulf) shrimp fishery, however, have yet to be examined.

Economic analysis of the fishing industry has increased in recent years because of the growing importance of world fish stocks. However, these studies have been focused predominantly at the micro or firm level (Thompson et al. 1970[2]; Wilson et al. 1970; Juhl 1974; Watson 1977; Griffin et al. 1978; Prochaska and Cato 1981). Moreover, accounting for a comprehensive mean of the cost of capital has been ignored in past research efforts. Yet, the cost of capital is likely a major factor in fishing vessel investment decisions in the Gulf shrimp fishery. The long run profitability of the sector and its exposure to financial risk depends, to a large extent, upon its capital structure and fluctuations in the cost of debt and equity capital. Futhermore, this determinent of aggregate investment behavior represents a major channel through which macroeconomic policy actions are transmitted to the Gulf shrimp fishery.

The purpose of this study is to estimate an econometric model of annual real net investment in fishing vessels in the Gulf and to determine the sensitivity of investment decisions in the industry to fluctuations in the cost of equity and debt capital. This study begins by examining the individual factors that affect the expansion of the stock of steel, wood, and fiberglass vessels in the Gulf fleet. The effects of alternative macroeconomic policies on investment expenditure trends in the Gulf shrimp fishery are then studied. The final section of this paper presents some concluding remarks.

Determinants of Net Investment

The aggregate investment model used in this study is based upon the neoclassical theory of aggregate investment behavior. The determinants of the desired capital stock of fishing vessels as well as the relationship between this desired capital stock and net investment behavior of Gulf shrimp fishermen are specified in this section.

Desired Stock of Fishing Vessels

In making investment decisions, competitive firms add to their existing stock of capital as long as the present value of the periodic net cash flows generated by an additional unit of capital exceeds its net purchase price. This condition for any particular type of fishing vessel (e.g., wood, steel, fiberglass) can be stated algebraically as follows[3]:

$$\sum_{t=1}^{\infty} p(\partial X/\partial K_j) - (\partial T_t/\partial K_j) - r(\partial D_t/\partial K_j) - (\partial P_t/\partial K_j)(1+\rho)^{-t} > q_j(\alpha - i_c) \times \Big(1 + \sum_{t=1}^{\infty} \partial R_{jt}/\partial K_j\Big)(1+\rho)^{-t}\Big) \qquad (1)$$

where variable p represents the real price fishermen expect to receive per unit of output in the Gulf of Mexico shrimp industry, X represents the quantity of shrimp expected to be harvested, K_j is the real stock of the j^{th} category of fishing vessels, T_t and P_t represent the tax payment and principal payment due in period t expressed in constant

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[2]Thompson, Russel G., R. W. Callen, and L. C. Wolken. 1970. Optimal investment and financial decisions for a model shrimp fishery firm. Unpubl. Rep. Texas A&M Univ., TAMU-SG-70-205.

[3]The variables without any subscripts are expected at the time the investment is made to remain constant over time.

dollars, D_t represents debt outstanding in period t, r is the real rate of interest on debt capital, ρ is the real after-tax opportunity rate of return on equity capital desired by fishermen, q_j is the real price paid for the j^{th} category of fishing vessels at the retail level, α is the proportion of investment financed with equity capital, i_c is the investment tax credit rate, and R_{jt} represents the real level of replacement investment in the j^{th} category of fishing vessels required in period t to offset losses in productive capacity due to wearout.

The entire term on the left-hand side of the inequality sign in Equation (1) represents the present value of the additional net cash flows generated by a permanent addition to the j^{th} category of fishing vessels. It is assumed that both the interest and the principal payments, $(\partial P/\partial K_j)$ and $r(\partial D/\partial K_j)$, vary over time as further expenditures are required to maintain the productive capacity of this addition to the capital stock at its original level. The right-hand side of Equation (1) represents the initial downpayment minus the investment tax credit plus the present value of all future cash outlays required to maintain the stock of the j^{th} category of fishing vessels at its new level.

To maximize the present value of their equity, Gulf shrimp fishermen would continue to add to the stock of the j^{th} category of fishing vessels until Equation (1) holds as an equality. Equivalently, maximization of the present value of owner equity requires that[4]

$$p(\partial X/\partial K_j) = \frac{q_j \rho}{(1 - F_j)} \cdot \frac{\alpha - i_c + Z - A}{(1 - i_Y)} \qquad (2)$$

where F_j represents the present value of the stream of capacity depreciation of the j^{th} category of vessels and i_Y is the average income tax rate. The term Z represents the present value of the stream of after-tax interest payments and principal payments on debt while A represents the present value of the stream of tax depreciation allowances that can be claimed for each dollar of investment as the stock of vessels is maintained at its new level.[5] The right-hand side of this expression thus represents the implicit rental price of the j^{th} category of fishing vessels.

The concept of the implicit rental price of capital has been widely employed in previous studies of investment behavior as a determinant of the capital stock which firms desire to hold (e.g., Coen 1968, 1975; Penson et al. 1981). Equation (2) suggests that the implicit rental price of the j^{th} category of fishing vessels will increase if their purchase price, the cost of debt, and equity capital, or income tax rates increase. These effects, however, will be offset to some extent by an increase in the investment tax credit rate, the deductibility of tax depreciation allowances, and interest expenses.

Let us assume that output in this industry is a function, in part, of the stock of fishing vessels and that this production relationship is of the Cobb-Douglas form. Letting β_j represent the partial production elasticity associated with the stock of the j^{th} category of fishing vessels (K_j), the marginal physical product for these vessels can be expressed as follows:

$$(\partial X/\partial K_j) = (\beta_j(X/K_j). \qquad (3)$$

Substituting Equation (3) into Equation (2), the desired stock of the j^{th} category of fishing vessels at the end of year t can be expressed as follows:

$$K^*_{jt} = \beta_j(pX/c_j)_t \qquad (4)$$

where c_j represents the expected implicit rental price of the j^{th} category of fishing vessels given by the right-hand of Equation (2). Equation (4) implies that the desired stock of j^{th} category of fishing vessels is directly related to the expected real gross income from Gulf shrimp fishing and is in-

[4]Equation (1) as well as the derivation of the implicit rental price of vessels (c) assume that fishermen expect real prices (p) and the marginal physical product of vessels $\partial X/\partial K$ to remain at current levels. These and other assumptions which allow us to treat many components of Equation (1) as consoles are consistent with those employed in Penson et al. (1981) and Coen (1975).

[5]The nominal value of Z (the present value of the stream of after-tax loan payments) in Equation (2) is equal to

$$(1 - i_Y)\Psi \sum_{i=1}^{n} d_i(1 + \phi)^{-i}(1 + \rho)^{-i} + \Psi \sum_{i=1}^{n} (e - d_i)(1 + \phi)^{-i}(1 + \rho)^{-i}$$

while the real value of A (the present value of the stream of depreciation allowances is equal to

$$i_Y(\delta/(\rho + \phi + \rho\phi + \delta))$$

where d_i is equal to the nominal interest payment on a loan of one constant dollar, ϕ is the inflation rate, e is the nominal amortized loan payment on a loan of one current dollar, and δ is the tax depreciation rate given by $2/n$ where n is the service life of the vessel.

versely related to the expected implicit rental price of these vessels. Similar equations could be developed for other inputs used in the shrimp fishing effort.

Desired Net Investment in Fishing Vessels

New fishing vessels are acquired by Gulf shrimp fishermen both to expand their productive capacity and to replace losses in the productive capacity of existing vessels. This partitioning of observed gross investment into net investment and replacement investment for the j^{th} category of fishing vessels can be expressed definitionally as follows:

$$N_{jt} = K_{jt} - K_{jt} = I_{jt} - R_{jt} \tag{5}$$

where I_{jt} represents the level of real gross investment in the j^{th} category of fishing vessels in year t while R_t is the real replacement investment needed to offset annual capacity depreciation of these vessels. The variables K_t and K_{t-1} represent the productive capital stock of the j^{th} category of fishing vessels the end and the beginning of the year, respectively. Given Equations (4) and (5), the following relationship between the desired stock of the j^{th} category of fishing vessels and current real net investment in these durable inputs can be defined:

$$N_{jt} = \theta_j(K^*_{jt} - K_{jt-1}) \tag{6}$$

where $0 < \theta_j \leq 1$ and where θ_j represents the partial adjustment coefficient that describes the speed of adjustment of actual stocks to desired levels for the j^{th} category of fishing vessels. Substituting Equation (4) into Equation (6) and assuming an adaptive expectations hypothesis for $(pX/c_j)_t$, the following compound geometric expression is obtained:

$$N_{jt} = \theta_j\ \beta_j\lambda(pX/c_j)_t + (1 - \lambda_j)N_{jt-1} + \theta_j(1 - \lambda_j)K_{jt-2} - \theta_j K_{jt-1} + \mu_{jt} \tag{7}$$

where λ_j is the adaptive expectations coefficient and μ_{jt} represents the error term. Since K_{jt-2} is equal to $K_{jt-1} - N_{t-1}$, Equation (7) reduces to the following estimating equation:

$$N_{jt} = b_{j0} + b_{j1}\ (pX/c_j)_t + b_{j2}\ K_{jt-1} + b_{j3}\ N_{jt-1} + \mu_{jt} \tag{8}$$

where b_0 is the intercept, $b_1 = \theta\ \beta\lambda$, $b_2 = -\theta\lambda$, $b_3 = (1 - \lambda)\ (1 - \theta)$ and μ_t is once again the random disturbance term. The estimates of the b_1 and b_3 coefficients are expected to be positive while the value of b_2 is expected to be negative.[6] Equation (8) thus represents the general form of the equations to be econometrically investigated in this study.

Data

The time series data used in this study consist of annual observations for each variable in Equation (8) over the 1965-77 period. This time period represents the only period for which investment expenditure information is available.

The productive capital stock of the j^{th} category of fishing vessels is comprised of a series of different vintages of vessels or

$$K_{jt} = I_{jt} + (1 - h_{j1})I_{jt-1} + (1 - h_{j1} - h_{j2})I_{jt-2} + \ldots + (1 - h_{j1} - h_{j2} - \ldots - h_{jn})I_{jt-n} \tag{9}$$

where h_{ji} is the fraction of the j^{th} category of fishing vessel's original productive capacity lost in the i^{th} year of its service life. The value of h_i is represented by $(1 - \phi)^{i-1}$, where $\phi = 2/n$ and n is the assumed service life.[7] In a related matter, the present value of the stream of capacity depreciation of a vessel (F_j) was computed as follows:

[6]The net investment model expressed in Equation (8) can be seen as a part of a simultaneous equation system that includes other investment equations as well as supply equations for all inputs and the production function for the fishing industry. The specification of the complete simultaneous system of equations and measurement of time series data needed to simultaneously estimate the b_i coefficients in Equation (8) are beyond the scope of this study. Since the disturbance terms for this set of investment equations are likely correlated, the seemingly unrelated regression equations estimator was employed. The disturbance terms given by this estimator were also examined for autocorrelation. The estimated rho coefficient in this small sample was shown to be insignificant in all cases. Finally, the predicted rather than actual value of N_{t-1} was used in estimating Equation (8) to address the possibility of correlation between the lagged dependent variable and the disturbance term.

[7]While a geometric decline in productive capacity has been assumed for fishing vessels, recent studies indicate that the productive capacity of equipment and machinery deteriorates at a lower rate in the early period than in latter years. Coen (1975) suggested that equipment and machinery deteriorate as they age, though not necessarily at a geometric rate. For farm tractors, a concave decay pattern represents the best proxy for the capacity depreciation pattern suggested by engineering considerations (Penson et al. 1981). The true pattern which underlines actual capital spending decisions in the fishing industry could not be examined due to inadequate data.

$$F_j = \sum_{i=1}^{\infty} h_{ji}(1 + \rho)^{-i} \quad (10)$$

Data from the National Marine Fisheries Service were used as annual observations on the nominal value of gross investment in Gulf fishing vessels (U.S. Department of Commerce 1965-77[8]). These values were deflated to real terms using the industrial price index. The quality of the time series for real net investment in fishing vessels, N_t, depends on how well the annual values of I_t reflect quality changes in vessels over time.

The annual levels of the implicit rental price of vessels (c) were computed using the definition outlined on the right-hand side of Equation (2). Coen (1975) assumed that the real after-tax rate of return desired on equity capital, ρ, is constant over the economic life of the investment. Following the lead of Coen, a value for ρ of 5% was employed in this study.

The real rate of interest on nonreal estate loans at commercial banks, r, along with annual rate of inflation equals the nominal rate of interest on debt capital. Annual values for all these variables were obtained from U.S. Department of Commerce publications. The annual values for the fraction of investment expenditures that are debt financed (ψ) used in computing Z were found by dividing the annual change in total debt in the fishing industry by the annual level of gross investment in durable inputs provided by the National Marine Fisheries Service. The time series for a, the fraction of capital expenditures financed with internal equity capital, was equal to one minus the percentage debt financed $(1 - \psi)$.

Investment tax credit rate, i_c, was equal to 7% during the 1965-68 period, 0% during the 1969-70 period, and 10% during the 1971-77 period. The maximum corporate income tax was assumed to represent i_v for the Gulf shrimp fishery. The double-declining balance method was assumed in determining the present value of the stream of annual tax depreciation allowances in A.

The time series data on prices paid for vessels, a component of the rental price, were measured using cost data collected from shrimp vessel builders. Griffin et al. (1978) have shown that vessel length, material of construction, and year of purchase were the most significant factors determining the price of a vessel. The equation estimated in that study was used to extend available vessel price information over the entire time period covered by this study.

[8]U.S. Department of Commerce. 1965-77. Vessel characteristics data. National Marine Fisheries Service, NOAA, Wash., D.C.

Econometric Results

Statistical as well as economic criteria can be employed to evaluate the estimated equations for the various categories of fishing vessels. The economic criteria include the reasonableness of the elasticities for the economic variables and as well the partial production elasticities implied for the production function.

Empirical estimates of the annual real net investment model for steel, wooden, and fiberglass vessels indicate statistically significant coefficients for all but one of the explanatory variables at the 10% level or less (Table 1). The lone exception was the coefficient associated with the lagged capital stock variable in wooden vessel model, which was not significantly different from zero at less than the 20% level. All the coefficients associated with the explanatory variables have the signs hypothesized earlier in this paper. Finally, the coefficients on the lagged dependent variable satisfy the constraint of being both greater than zero and less than one.

TABLE 1.—Estimated coefficients for the annual net investment model for fishing vessels. Gulf Shrimp Fleet, 1965-77.

Vessel type	Constant (b_0)	$(pX/c)_t$ (b_1)	K_{t-1} (b_2)	N_{t-1} (b_3)
Steel	−95.3895	4.3770	−9.1302	0.6318
		[1](6.21)	(6.23)	(2.34)
Wooden	384.3848	0.1132	−3.1944	0.9089
		(1.79)	(0.93)	(1.21)
Fiberglass	0.3819	0.2990	−0.9529	0.2765
		(5.37)	(1.74)	(2.88)

[1]Numbers in parentheses indicate absolute values of t-statistic.

Economic criteria employed in evaluating the reasonableness of the empirical results and in comparing the investment behavior among vessel types include the partial production elasticity of fishing vessels (β). This elasticity is given by $-b_1/b_2$ which is computed using the estimated beta coefficients in Equation (7). It appears that steel vessels, with a partial production elasticity of 0.479, are highly productive and play an important role in the supply of fish. The fishing sector, unlike other sectors of the economy, depends primarily on one major capital input—vessels. Therefore, the high partial production elasticities recorded for steel vessels and fiberglass vessels (0.314) are no surprise. Even though wooden vessels appear to incur more repair and maintenance costs, attract a lower quality crew, and, for that matter, are less efficient than the other vessel types, the low partial production elasticity of 0.033 is surprising. This low partial production elasticity may have been caused by the fact that the instrument for N_{t-1} in the wooden vessels equation used to address the issue of the relationship between the lagged dependent variable and the error term did a poor job of explaining N_{t-1}.

An examination of the elasticities associated with the $(pX/c)_t$ term, computed at the mean, reveals that real net investment in steel vessels is the most sensitive to changes in prices, interest rates, taxes, and the other factors captured in this variable. An elasticity of 7.28 associated with this economic variable was computed for steel vessels. This means that a 1% change in the $(pX/c)_t$ variable causes real net investment in steel vessels to change by 7.28%. This high investment response to changes in these economic relationships could be attributed to the fact that steel vessels, by far the most productive (as evidenced by the high partial production elasticity reported earlier), are the most durable and the most capital intensive. The elasticity associated with the $(pX/c)_t$ term in the fiberglass and wooden vessel equations were 5.35 and 3.11, respectively. This would suggest that macroeconomic policy actions would have a substantially greater effect on real net investment in steel vessels than, say, wooden vessels.

Impact of Changes in Cost of Capital

The impact of high real interest rates on the growth of selected sectors in the economy has been of great concern in the 1980s. The sensitivity of annual real net investment in fishing vessels to changes in the real rate of interest is examined in this section by simulating the estimated equations under annual real rates of 5 and 10%. In the short run (3 years), an increase in the real rate of interest on debt capital from 5 to 10% would cause real net investment in fishing vessels to decrease by 3.04%. Annual real net investment in these fishing vessels would decrease by 15.88% in the long run. As the real rate of interest on debt capital increases, it becomes more difficult to justify the purchase of additional vessels owing to their rising marginal factor cost. Given the fact that 67% of the cost of new fishing vessels is normally financed with debt capital, it is not surprising that rising real interest rates on debt captial have a significant negative effect on the long run expansion of the Gulf fleet.

The real cost of equity capital, which reflects the opportunity cost of the fisherman's own funds, has a less dramatic effect on annual real net investment in fishing vessels. This can be attributed to the fact that only 33% of the cost of new fishing vessels are financed with equity capital. The short run impact of an increase in the real cost of equity capital from 5 to 10% translates into only a 1.76% decrease in annual real net investment in fishing vessels in the short run. This same change in the cost of equity capital would result in a 12.32% decrease in annual real net investment in the long run.

Summary and Conclusions

This study evaluated aggregate investment behavior by fishermen for steel, wooden, and fiberglass fishing vessels in the Gulf of Mexico shrimp fishery and examined the implications of changes in the cost of acquiring debt and equity capital on the industry's investment response. This study showed statistical justification for the theoretical model of aggregate investment behavior for all three vessel types.

It is quite evident that the cost of capital plays an important role in influencing the investment decisions in the Gulf shrimp fishing industry. Macroeconomic policies that lead to high real interest rates depress real net investment in this fishery. Capital expenditures for steel vessels are the most sensitive to changes in real interest rates while wooden vessels are the least sensitive. While low real interest rates are desirable for stimulating investment activities in the general economy, they would add to the overcapitalization problem which currently exists in the Gulf shrimp fishing industry. Finally, this study underscores the need to reinitiate efforts to collect data on gross investment expenditures for different categories of fishing vessels in the Gulf fleet.

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APPENDAGE INJURY IN DUNGENESS CRABS, *CANCER MAGISTER*, IN SOUTHEASTERN ALASKA

The Dungeness crab, *Cancer magister*, is commercially important along the western coast of the United States. Like many decapod crustaceans, it can autotomize and regenerate appendages to heal wounds and limit injury.

Studies of appendage injury may be useful in assessing the physical condition of crustacean populations and the impact of fishing on commercially important species. Incidences of appendage loss in the field have been reported for species of crabs other than *C. magister* (McVean 1976; McVean and Findlay 1979; Needham 1953). Appendage loss was studied in adult Dungeness crabs in Washington (Cleaver 1949) and Oregon (Waldron 1958) and for juvenile crabs in the Columbia River estuary (Durkin et al. 1984).

In this study we examined adult Dungeness crabs in southeastern Alaska to determine the incidence of missing, regenerating, and damaged appendages. Temporal incidence of appendage injury was compared to the molting and mating periods of the crabs and to the commercial fishing season for Dungeness crabs.

Materials and Methods

Adult Dungeness crabs were collected from Icy Strait and the Excursion Inlet fjord near Glacier Bay, AK (lat. 135°30′N, long. 58°25′W), from May through November 1984-85. Data were obtained by monthly surveys of commercially caught crabs. Crab pots (Waldron 1958) were set at depths of 7 to 20 m and remained in the water for 3 to 11 days. All crabs were held in live tanks (<24 hours) before they were measured on board ship. In southeastern Alaska, pots are equipped with escape rings to permit release of crabs with carapace widths <165 mm, but sublegal-sized crabs are often found in the catch.

Carapace width (excluding the 10th anterolateral spines), wet weight, and sex were recorded for each crab. Carapace condition was graded as soft-shell (recent molt), new-shell, worn-shell, or skip-molt (Somerton and Macintosh 1983). The number and identities of missing, damaged, or regenerating chelipeds and walking legs were recorded. An appendage with a cracked cuticle or missing dactyl was considered damaged. Appendages smaller in length and diameter than intact appendages were designated regenerating. Combined missing, damaged, and regenerating appendages are referred to as injured appendages.

Interrelationships between variables were determined with Pearson correlations (SAS 1985). Means were compared with Student's t-tests, and chi-square analyses were used to determine if multiple autotomies occurred by chance (Steel and Torrie 1960). Data are presented as means ±1 standard error of the mean.

Results

Males comprised 65% and females 35% of the 878 Dungeness crabs examined. Average carapace widths were 169 ± 0.6 and 159 ± 0.7 mm for males and females, respectively. Wet weights were 1,102 ± 9 g for males and 884 ± 14 g for females. The greatest number of female crabs was caught in July, and the greatest number of males in August.