Bangladesh J. Agric. Econ. XIV, 2 (December 1991) 51-72

A PROFIT FUNCTION ANALYSIS OF MULTISPECIES FISHERY IN MALAYSIA : IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

Production behaviour, input-output response and characteristics of gillnet technology have been investigated using the data from Peninsular Malaysia. Results showed that gillnet fishermen cannot maximize profit. Most of the product supplies are non-responsive to price changes. Input demands, however, are responsive to their price changes. Complementarity exits among the species caught. Variable inputs are also complementary to each other. Input-output relationships are separable and non-joint. The study provides empirical support that open-access to fishery results in over utilization of resources. Some form of regulations is warranted to restrict fishing effort. Regulation prohibiting catch of selected species seems to be quite appropriate and consistent as far as the gillnet technology is concerned.

I. INTRODUCTION

Inspite of the joint production of outputs in much of the world's agriculture, production relationships between outputs and inputs of multi-product firms has commonly been overlooked due to limitations associated with traditional functional forms (Duloy, 1964). As a result of aggregation of output, many earlier studies have been unable to shed any light on the relationship between inputs and specific outputs and the relationship between various alternative outputs (Lau and Yotopolous, 1972; Vincent, 1977). In the capture fishery,

The author is an Associate Professor, Department of Agricultural Finance, Bangladesh Agricultural University, Mymensingh. The paper is derived from his Ph.D. thesis submitted to the Universiti Pertanian Malaysia. He is grateful to his supervisor Professor Dr. Muhammad Ariff Hussain, and Dr. Dale Squires, Economist, National Marine Fisheries service, California for their valuable comments and suggestions. However, the author alone remains responsible for errors, if any, in the manuscript. Winrock International and Asian Fisheries Society are gratefully acknowledged for providing financial assistance in completing the research.

characteristics of multiproduct technology such as input-output separability and jointness in inputs are commonly ignored. Many of the production function related studies conducted earlier (for example, Fredericks and Nair, 1985; Jahara, 1984a, 1984b; Tokrisna *et al.*, 1985; Khaled, 1985) did not take these aspects into consideration. Fortunately, the development of some flexible functional forms has made it possible to test for these characteristics.

Production function approach is one of the popular methods of estimating farmer's response to changes in prices of their farm products. In this method derived input demand functions are obtained by solving simultaneously, the production function and the marginal productivity condition as has been done by Sidhu (1974). However, since the production function considers quantities of inputs as the independent variables, elasticity estimates obtained through it tend to suffer from bias. In a production system, the production function may be considered to be a non-isolated relationship. Data observations are generated by profit maximizing or cost minimizing considerations of the farm and, as a result, the output and input levels are simultaneously determined. The production function is therefore only one of a system of simultaneous equations, and single equation estimates in general are biased and inconsistent. This results from the fact that the level of factor use does not only depend on the output and respective factor prices but also on the error term of the production function, thus violating the assumptions of the least square estimation of the production function (for example, see, Walter, 1963; Zellner *et al.*, 1966, and Yotopolous and Nugent, 1976).

By making use of the duality theory, the present study has developed a multi-product profit function through a flexible translog functional specification to account for the inherent weaknesses of the single equation estimation made through traditional functional forms (see, Chand and Kaul, 1986 for weakness associated with Cobb-Douglas functional form). Translog, being a flexible function, provides added opportunities to test for the characteristics of a multiproduct technology. The particular areas of investigation include nature of production behaviour of fishermen, output (fish) supplies and input demand response, and characteristics of gillnet technology being applied to harvest multiple species from open-access common property fishery in Peninsular Malaysia. The use of a multiproduct profit function to analyse production relationships in the concerned 'capture fishery' is a new application of the duality theory. It is expected that the analysis will generate useful information for the management of capture fishery of the developing nations.

The paper is organised as follows. Section II describes briefly the nature and characteristics of gillnet fishery and the fishing technology. Section III deals with the data, methodology and the analytical model. Findings of the study are discussed in section IV. Finally, conclusions and policy implications are made in section V.

II. NATURE OF FISHERY AND CHARACTERISTICS OF FISHING TECHNOLOGY

The Fishing Industry

The fishing industry of Peninsular Malaysia is a relatively small subsector of agriculture contributing only 2.3% to GDP (Department of Fisheries, 1990). The marine fishery in Malaysia is the dominant fishing sector contributing about 95% of total fish production. Artisanal fishery is the mainstay of the Malaysian fishing industry. Technological dualism is apparent as both commercial gear like trawler, purse seine coexist with a large number of traditional fishing methods such as drift/gillnets, liftnet, bagnet, scoopnet, and hooks and lines.. About 54% of all gear types are gillnets contributing 6.3% of total marine landings of the Peninsular Malaysia. The trawlnet and purse seine constitute 20 and 8% of all gear types which contribute respectively 57 and 20% of the total marine landing. Although gillnets contribute very- little but huge number of fishermen maintain livelihood with this.

Operation of Gillnet and Catch Composition.

The marine fishery of Peninsular Malaysia is Multispecies in nature. The fishing firms operating in this fishery often harvest multiple species with level and mix of catch as decision variables depending upon the types of gear used and mechanization of boat/vessel. Although level and mix of catch are to a great extent decision variables in the capture fishery, the gillnetters produce non-targeted catch too.

Gillnets used in Peninsular Malaysia are of different types such as *pukat jarung, pukat hanyat and pukat dalam.*. Nets are so designed as to entrap, entangle or encircle fish during operations. Usually gillnets are set across the direction of the migrating fish, so that they try to make their way through the meshes of netting. In trying to swim through a mesh of netting which is a little smaller than the largest circumference of their body, they get stuck, or, in other words, meshed. By struggling to become free from the mesh the fish further entangle itself. Once the fishes are meshed, the nets are taken out of water either manually or mechanically in order to disentangle fishes from the meshes. The catches are stored in deck of the boat/vessel. The dominant species vulnerable to gillnets are Pomfret, Spanish Mackarals, Wolf Herring, Shads, Horse Mackarals, Hardtail' Scads. Selar Scad, Tuna, Black Kingfish, Crab, Marine Catfish, Jewfish, Indian Mackarals, Gizzard Shads, Queenfish, and Sharks. Although meshes can be designed in the light of the species in view, the ultimate catch invariably results in a mix of different species: The catches are harvested by organizing fuel/energy, labour/crew, and capital (boat, engine, gear, net, and a set of fishing accessories).

Characteristics of Fishing Trip

The average length of hull of sample boat/vessel is about 12 meters. Gross Registered Tonnage (GRT) was 10.57 on the average. All the surveyed boats had inboard engines, the average horsepower of which was about 26. Number of trips made at sea by the gillnetters was 19 per month. Trip duration was 1.14 days. Thus, the total fishing days per month is 22. Average distance covered by the gillnetters was about 10 nautical miles. Average haul made per fishing day was 2.00. The surveyed gillnetters had a mean crew size of 3.16.

Characteristics of Multispecies Fishing Technology

Two of the important characteristics of the multispecies fishing technology are input-output separability and jointness-in-inputs production which have important implications for fishery management. Separability is the relevapt property of technology which allows aggregation of individual inputs into the aggregate variable fishing effortl. Several types of separability exists, but the relevant type for aggregation is weak separability. Weak separability requires that marginal rates of technical substitutions (MRTS) between all pairs of variables in a particular group (such as fishing effort) are independent of changes in the levels of variables not in that group (output). Strong separability is a more restrictive form of separability, and requires that the MRTS between variables of different group be independent of the levels of the variables in any other group. Strong separability implies weak separability, but the converse applies when only two sub-sets exist. Separability can occur at various levels of aggregations. At the highest level, separability between inputs and outputs implies composite indices for both total cak:fv and effort. An input-output separable technology implies that fishermen make their decision on optimal species independently of their decisions on factor combination. Fishermen select their species on the basis of expected relative species prices and prior knowledge subject to the technological constraints imposed by resource availability and weather conditions. Alternatively, changes in relative species prices do not affect production decisions on the optimal combinations of inputs used.

Joint-in-inputs multiproduct production requires all inputs to produce all outputs, while non-joint-in-inputs implies separate production function for each output or set of outputs and decisions about production of a particular species are independent of decisions about other species.

These two characteristics of the multispecies technology have far reaching implications for fishery management. The commonly maintained hypothesis, i.e., existence of composite 'effort' and aggregate 'single' output index is valid under a fairly restrictive assumption. If the technology does not satisfy these restriction then input-output aggregation in the form of composites may provide misleading information and the fishery managers are *often misguided leading to failure offishery regulations.*

III. DATA, METHODOLOGY AND THE MODEL

The present study utilizes the duality theory to study the production *relationships between outputs and inputs in a common property*[2] *fishery of* Peninsular Malaysia. Cross-sectional data are used for testing the main hypotheses relating to input-output separ4bility, jointness-in-inputs production and profit maximizing behaviour of the gillnet fishermen. The use of crosssection data in profit function framework poses some problems (see, Quiggin and Builan, 1984). The arguments of a profit function are price variables and these, are not likely to vary greatly between firms at a single point of time and location. In a perfectly competitive market, all firms at a given time and place face the same vector of prices. However, in cross-sectional studies, it is generally assumed that differences in time are excluded and variations in the vector of actual prices faced by firms come only from differences in locations or from variations of the competitive assumptions. If differences in locations are an important source of price variation, then there does not appear to be any theoretical difficulty in estimating the cost and profit functions, nor in testing for efficiency differences between groups of firms. In order to have reasonable variability among the vectors of prices, data were collected from several selected locations of the east coast of Peninsular Malaysia.

A multistage sampling procedure was administered in selecting the sample fishing firms. The first and second stages were respectively the selection of states and fisheries districts within the states. Based on the criteria of the concentration of the concerned gear, selected locations of the states of Terengganu, Pahang and East Johor were chosen as the study area. A total of 42 gillnet fishermen from the selected locations constitute the total sample. As staged earlier, the fishery under consideration is multispecies in nature and therefore, a large number of species were required to be aggregated in order to accommodate the multiple outputs and inputs in the the profit function model. The aggregation was made on the basis of the grading system of the Department of Fisheries, Malaysia, for different species caught and sold in Malaysia[3]. The different species vulnerable to the gillnet were aggregated into three grades namely, high-grade, medium-grade and low-grade. The aggregation of species made in the present study followed the geometric weighted average procedure. Geometric mean prices and an implicit quantity index of catch were computed since prices of variable output-input are the main concern of the profit function approach (see, Alam, 1991 for details.)

Production Frontier and Profit Function

In specifying the short-run production technology the study specified three aggregated species, two variable inputs namely, energy (diesel/petrol and lubricant) and crew/labour implicit wage[4], and a quasi-fixed factor (boat/vessel size) represented by the gross registered tonnage (GRT). Shortrun restricted profit was defined to be the total revenue from the sale of species minus the cost of energy consumption and total implicit labour/crew wage. It is assumed that in each of the period fishing boats maximize short-run profit subject to their fishing technology set and vessel/boat size.

With the kind of aggregation in fish species, the structure of production technology of the gillnet fishermen may be explained by the following implicit production frontier:

$$F(y_H, y_M, y_L, x_E, x_W; Z) = 0 \quad (1)$$

where:

y_H = quantity of high-grade species caught

y_M = quantity of medium-grade species caught

y_L = quantity of low-grade species caught

x_E = quantity of energy consumed in fishing

x_W = quantity of onboard crew/labour employed

Z = vessel/boat size represented by gross registered tonnage (GRT)

Given the production frontier as in (1), the short-run profit maximizing behaviour of the gillnet fishermen is:

$$\text{Max } \pi = p_H y_H + p_M y_M + p_L y_L - p_E x_E - p_W x_W \quad (2)$$

subject to the production frontier (1), where F(.) represents the production possibilities of combining the variable inputs with the quasi-fixed factor vessel size in determining the catch quantities of aggregated high-grade, aggregated medium-grade and aggregated low-grade species. By specifying the production possibility set with respect to catch quantities, it is implicitly assumed that catch quantities are proportional to fishing effort (see, Hannesson, 1983).

Equation (2) is referred to , in duality literature, as a direct profit function. An important concept in the dual approach is that of an indirect profit function, defined as the maximum profit associated with given species prices and variable input prices. The indirect profit function can be obtained by solving for the optimal quantities of output-input and substituting them in equation (2), yielding the following equation:

$$\pi^* = p_H y_H + p_M y_M + p_L y_L - p_E x_E - p_W x_W \quad (3)$$

Equation (3) provides the maximized value of profit for each set of p_i, i= H,M,L,E.W. This restricted profit as in (3) is expressed as a function of the variable output-input price vector and quantity of the quasi-fixed factor. Therefore, the short-run or restricted profit function obtained by solving equation (3) with respect to prices and quasi-fixed quantities can be represented as:

$$\pi^* = \pi^* (p_H, p_M, p_L, p_E, p_W; Z) \qquad (4)$$

where, π^* represents the short-run or the restricted profit.

Hotteling's Lemma provides $\delta\pi^*/\delta p_i = Y^*_i \ (p_i;Z)$ (5)

where i = H,M,L,E,W (Beattie and Taylor, 1985). The positive derivative of Eqn. (5) with respect to prices of product i (species) results in the product supply equation while that of the negative one with respect to the prices of variable inputs yields the variable input demand equation.

In order to estimate the price response of variable output-input to the quantity, a functional form of $\pi(.)$ is necessary for which a translog function is chosen so as not to impose *a priori* restrictions on the summary elasticities. This functional form is flexible and allows the specific features of technology and does not restrict the Allen Partial Elasticity of Substitution. Ray (1982) indicated that the function allows modeling production alternatives and measuring both input substitutability and complementarity. Moreover, this functional form has the added advantage of testing as to whether the squared and the cross interaction terms are significant - an indication of which reduces the translog specification to the well known Cobb-Douglas specification (Mefford, 1986).

The Model

By duality and by assuming that fishing firms maximize short-run profits and operate within competitive factor and product markets, a flexile[5] translog function was specified as a second-order Taylor series approximation around the unit price vector with all variables being scaled by geometric mean. The multiproduct-multiinput profit function of the gillnet fishermen defined over three aggregated output species, two variable inputs and one quasi-fixed factor along with some dummy variables was specified as:

$$\ln\pi = \alpha_o + \alpha_H \ln P_H + \alpha_M \ln P_M + \alpha_L \ln P_L + \alpha_E + \alpha_W \ln P_W$$

$$+ \alpha_Z \ln_Z + .5\, \alpha_{HH} (\ln P_H)^2 + .5\, \alpha_{MM} (\ln P_M)^2 + .5\, \alpha_{LL} (\ln P_L)^2$$

$$+ .5\, \alpha_{EE} (\ln P_E)^2 + .5\, \alpha_{WW} (\ln P_W)^2 + .5\, \alpha_{ZZ} (\ln Z)^2$$

$$+ \alpha_{HM} \ln P_H \ln P_M + \alpha_{HL} \ln P_H \ln P_L + \alpha_{HE} \ln P_H \ln P_E$$
$$+ \alpha_{HW} \ln P_H \ln P_W + \alpha_{HZ} \ln P_H \ln Z + \alpha_{ML} \ln P_M \ln P_L$$
$$+ \alpha_{ME} \ln P_M \ln P_E + \alpha_{MW} \ln P_M \ln P_W + \alpha_{MZ} \ln P_M \ln Z$$
$$+ \alpha_{LE} \ln P_L \ln P_E + \alpha_{LW} \ln P_L \ln P_W + \alpha_{LZ} \ln P_L \ln Z$$
$$+ \alpha_{EW} \ln P_E \ln P_W + \alpha_{EZ} \ln P_E \ln Z + \alpha_{WZ} \ln P_W \ln Z$$
$$+ f_1 d_1 + f_2 d_2 + f_3 d_3 + u\pi \quad (6)$$

where:

π = Short-run restricted profit defined as total revenue from the aggregated species minus expenditures on variable inputs.

H = Aggregated high-grade species consisting of Pomfret, Spanish Mackarals, Wolf Herring and other irregularly appearing grade-A species.

M = Aggregated medium-grade species consisting of Shads, Horse Mackarals of different types and other irregularly appearing grade-B species.

L = Aggregated low-grade species consisting of Hardtail Scad, Selar Scad, Tuna, Black Kingfish, Crabs, Marine Catfish, Jewfish, Indian Mackarals, Gizzard Shads, Queenfish, Sharks and other irregularly appearing grade-C species.

E = Cost of energy (diesel-petrol and lubricant/oil) per fishing day.

W = Implicit wage (derived from share system) per crew per fishing day.

Z = Boat/vessel size represented by gross registered tonnage (GRT)[6].

α_i and α_{ij} are parameters to be estimated.

ln = Natural logarithm.

f_i (i=1,2,3) = parameters of dummy variables to be estimated.

d_1 (Ownership dummy) = 1 for owner captain and 0 otherwise

d_2 (Training dummy) = 1 for trained captain and 0 otherwise

d_3 (Race dummy) = 1 for Malay and 0 for Chinese

u_π= error term of the profit function

Share Equations

Product revenue and input cost share equations are derived using the above equation by applying the Hotteling's Lemma to the profit function. The product revenue and input cost share equations are as follows:

$$\delta \ln\pi/\delta \ln P_H = S_H = \Theta_H + \Theta_{HH} \ln P_H + \Theta_{HM} \ln P_M + \Theta_{HL} \ln P_L + \Theta_{HE} \ln P_E + \Theta_{HW} \ln P_W + \Theta_{HZ} \ln Z + u_H \quad (7)$$

$$\delta \ln\pi/\delta \ln P_M = S_M = \Theta_M + \Theta_{MH} \ln P_H + \Theta_{MM} \ln P_M + \Theta_{ML} \ln P_L + \Theta_{ME} \ln P_E + \Theta_{MW} \ln P_W + \Theta_{MZ} \ln Z + u_M \quad (8)$$

$$\delta \ln\pi/\delta \ln P_L = S_L = \Theta_L + \Theta_{LH} \ln P_H + \Theta_{LM} \ln P_M + \Theta_{LL} \ln P_L + \Theta_{LE} \ln P_E + \Theta_{LW} \ln P_W + \Theta_{LZ} \ln Z + u_L \quad (9)$$

$$\delta \ln\pi/\delta \ln P_E = -s_E = \Theta_E + \Theta_{EH} \ln P_H + \Theta_{EM} \ln P_M + \Theta_{EL} \ln P_L + \Theta_{EE} \ln P_E + \Theta_{EW} \ln P_W + \Theta_{EZ} \ln Z + u_E \quad (10)$$

$$\delta \ln\pi/\delta \ln P_W = -s_W = \Theta_W + \Theta_{WH} \ln P_H + \Theta_{WM} \ln P_M + \Theta_{WL} \ln P_L + \Theta_{WE} \ln P_E + \Theta_{WW} \ln P_W + \Theta_{WZ} \ln Z + u_W \quad (11)$$

where, S_i (i=H,M,L,E,W) are profit shares and u_i (i=H,M,L,E,W) are error terms of share equations.

The restricted profit function and the share equations have been jointly estimated with symmetry restriction imposed across equations (see Squires, 1987, 1988; Bjorndal and Gordon, 1988). Since the parameters of revenue and cost share equations are sub-sets of those of the profit equation (6), the inclusion of share equations increase, the number of available degrees of freedom. and improve statistical precision. As the shares sum to unity, their disturbances sum to zero. Hence, to avoid singularity of the covariance matrix of the error terms, equation 11, i.e., the labour share equation, was dropped from the system whose parameters may be derived from the symmetry and the homogeneity restrictions. The profit function (6) has an additive disturbance term due to approximation error, while the revenue and cost share equations (7-11) have additive disturbances from errors in optimization (Burges, 1975). The system consisting of equations 6, 7, 8, 9, and 10 was estimated by employing the SUR procedure. Without loss of generality, symmetry requiring $\alpha_{ij} = \alpha_{ij}$, $i \neq J$, and homogeneity in variable input-output prices requiring $\Sigma\alpha_i = 1$, and $\Sigma\alpha_{Hi} = \Sigma\alpha_{Mi} = \Sigma\alpha_{Li} = \Sigma\alpha_{Ei} = \Sigma\alpha_{Wi} = \Sigma\alpha_{Zi} = 0$ are directly imposed on profit function (6).

Partial Elasticities

The estimated profit function[7] was used to derive different partial elasticities. The formula used in estimating the elasticities are as follows:

$$\eta_{ii} = S_i - 1 + \alpha_{ii}/S_i \quad (12)$$

(i=H,M,L are output species) represents own price output supply elasticity.

$$\eta_{ij} = S_{ij} + \alpha_{ij}/S_j \quad (13)$$

(i,j are output species but $i \neq j$) represents cross output supply elasticity.

$$\eta_{rr} = -S_r - 1 - \alpha_{rr}/S_r \quad (14)$$

(r=E,L are variable inputs) represents own price input demand elasticity.

$$\eta_{rt} = -S_t + \alpha_{rt}/S_r \quad (15)$$

(r, and t are variable inputs but $r \neq t$) represents cross price input demand elasticity.

IV. RESULTS AND DISCUSSIONS

Goodness of fit

The economic significance of the estimated parameters of the jointly estimated profit function as presented in table 1 lies in the fact that they enable us to obtain empirical measures of elasticities of factor substitution, elasticities of factor demand, product supply, economies of scale etc. However, before discussing these aspects, the goodness of fit of the estimated profit model is examined.

In order for the translog to be an adequate representation of the underlying production structure, the estimated profit function must satisfy homogeneity of degree one in prices (i.e., a proportional increase in all prices implies a proportional increase in profit), monotonicity (i.e., predicted revenue shares must be positive and predicted cost shares must be negative) and convexity in prices (i.e., the Hessian of the profit function with respect to prices must be positive semidefinite) (Diewert, 1974).

Most of the above regularity conditions are satisfied. The underlying profit function was found to be homogeneous of degree one. Monotonicity is satisfied at all sample points. The Hessian of the profit function was positive definite. All of these results ensure the existence of duality between the profit and the underlying production function. In addition to the regularity conditions being satisfied, the model also fits the data well as evidenced by the system weighted R^2 of 0.80.

Table 1. Parameter Estimates of the Unrestricted and Various Restricted Profit Function for the Gillnet Firms.

Parameter	OLS estimate	Unrestricted estimate	Model (A)	Model (B)	Model (C)	Model (D)	Model (E)
			Seemingly Unrelated Regression Estimate (Zellner's Method)				
α_O	0.2889	0.2261	-0.0492	-0.0710	0.3600[b]	0.1572	0.1528[a]
	(1.160)	(1.418)	(-0.430)	(-1.167)	(2.235)	(1.003)	(2.742)
α_H	0.7958	0.6065	-0.1238[a]	-0.1960	-0.6162	0.5268	0.8015[a]
	(1.685)	(1.393)	(-0.290)	(-0.884)	(-1.258)	(1.590)	(32.226)
α_M	-1.0101[c]	-0.0296	-0.4071	-0.4465[c]	0.9831[b]	-0.9486[c]	0.2770[a]
	(-1.743)	(-1.193)	(-0.748)	(-1.755)	(2.239)	(-1.786)	(23.504)
α_L	-1.7185[a]	-1.6660[a]	-0.4131	-0.6692[c]	-0.0598	-1.3401[a]	0.9991[a]
	(-3.516)	(-3.295)	(-0.802)	(-1.796)	(-0.163)	(2.753)	(40.188)
α_E	-0.1519	-0.1016	-0.0159	-0.0891	0.1657	-0.1407	-0.1505[a]
	(-0.502)	(-0.361)	(-0.057)	(-0.430)	(0.580)	(-0.639)	(-34.719)
α_W	-0.0811	-0.0587	0.0288	-0.0176	0.1849	-0.0613	0.1428[b]
	(-0.657)	(-0.059)	(0.025)	(-0.168)	(1.630)	(-0.620)	(2.629)
α_Z	0.4626[a]	0.4331[a]	0.0446	0.1763[b]	0.3422[c]	0.3643[b]	0.2173
	(2.838)	(2.862)	(0.272)	(2.572)	(1.847)	(2.520)	(0.278)

Table 1. Continued

Parameter	OLS estimate	Unrestricted estimate	Model (A)	Model (B)	Model (C)	Model (D)	Model (E)
			Seemingly Unrelated Regression Estimate (Zellner's Method)				
α_{HH}	-0.7429	-0.9325	0.0877	e	-2.3958	-0.1284	0.2774[c]
	(-0.336)	(-0.461)	(0.093)		(-1.067)	(-0.076)	(1.845)
α_{MM}	8.3736	6.4703[b]	-1.1835	e	-3.2965	5.1033	-0.0121
	(1.720)	(1.451)	(-0.071)		(-1.040)	(1.692)	(-0.095)
α_{LL}	-2.9576	-2.7719	4.0653	e	-2.1838	-3.1020	0.1851
	(-0.614)	(-0.628)	(1.374)		(-0.693)	(-0.800)	(0.968)
α_{EE}	-1.9256	-1.5645	0.2892	e	-0.3761	-0.7620	-0.1411[a]
	(-1.439)	(-1.276)	(0.273)		(-0.295)	(-0.694)	(-8.001)
α_{WW}	-0.0570	-0.1756	-0.0996	e	-0.7516[b]	-0.0421	-0.1935
	(-0.167)	(-0.562)	(-0.447)		(-2.714)	(-0.139)	(-1.464)
α_{ZZ}	0.4497	0.6101	-0.0356	e	0.4794	0.3390	0.3896[a]
	(0.713)	(1.057)	(-0.131)		(0.890)	(0.636)	(4.640)
α_{HM}	1.0163	1.4048	2.2499	e	-0.5791	-0.5424	-0.1470[c]
	(0.188)	(0.284)	(0.513)		(-0.174)	(-1.590)	(-1.880)
α_{HL}	-0.0140	1.1552	0.1397	e	1.0044	-0.8779	-0.2722[c]
	(-0.003)	(0.297)	(0.048)		(0.347)	(-1.590)	(-1.961)
α_{HE}	1.5644	0.9563	e	e	-0.5051	0.7483	0.0389
	(0.764)	(0.510)			(-0.215)	(0.410)	(1.457)
α_{HW}	1.1342	1.0218	e	e	2.1718[c]	0.3763	0.4309[a]
	(0.828)	(0.815)			(1.865)	(0.328)	(5.822)
α_{HZ}	-3.0809	-2.0179	e	e	0.3043	-2.3519	0.1060
	(-1.720)	(-1.329)			(0.189)	(-1.749)	(1.520)
α_{ML}	3.6095	3.6214	-0.3320[b]	e	1.9207	-1.5809[c]	-0.1088
	(0.680)	(0.744)	(-2.725)	e	(0.189)	(-1.786)	(-0.911)
α_{ME}	-0.5174	-1.1964	e	e	-0.9552	0.7103	-0.0136
	(-0.189)	(-0.477)			(-.345)	(0.315)	(-0.385)

Table 1. Continued.

Parameter	OLS estimate	Unrestricted estimate	Model (A)	Model (B)	Model (C)	Model (D)	Model (E)
			Seemingly Unrelated Regression Estimate (Zellner's Method)				
α_{MW}	4.3912[a] (3.127)	4.3629[a] (3.393)	e	e	1.6321 (1.530)	3.9917[a] (3.137)	0.1777[a] (4.758)
α_{MZ}	4.7977[c] (1.906)	4.0844[c] (1.771)	e	e	1.2780 (1.100)	3.0841 (1.553)	0.0868[b] (2.266)
α_{LE}	4.1376 (1.186)	3.1181 (0.973)	e	e	-3.9490 (1.405)	2.6612 (0.838)	0.0156 (0.445)
α_{LW}	0.9301 (0.411)	0.1999 (0.096)	e	e	-3.1683[b] (-2.415)	0.8027 (0.426)	0.0158 (0.478)
α_{LZ}	1.5147 (0.593)	1.8104 (0.774)	e	e	-1.5219 (-1.2642)	1.2063 (0.524)	0.1405[c] (2.038)
α_{EW}	-0.5771 (-0.691)	-0.5969 (-0.780)	-0.5158 (-0.725)	e	-0.7279 (-1.145)	-0.2904 (-0.382)	0.0409[a] (4.032)
α_{EZ}	0.2670 (0.167)	-0.2489 (-0.170)	-0.6001 (-0.576)	e	-1.3839 (-0.854)	-0.0665 (-0.049)	-0.0019 (-0.142)
α_{WZ}	0.8665[c] (1.896)	1.0236[b] (2.466)	0.2517 (0.778)	e	0.8439[b] (2.510)	0.6803[c] (1.765)	0.3036[c] (1.926)
f_1	-0.2054[b] (-2.335)	-0.1729[b] (-2.146)	0.0253 (0.352)	0.3338 (0.714)	-0.1433 (-1.583)	-0.1327[c] (-1.891)	0.0114 (0.274)
f_2	-0.0454 (-0.548)	-0.0278 (-0.366)	0.0347 (0.458)	0.0223 (0.488)	0.0135 (0.160)	-0.0079 (-0.125)	0.0544 (1.352)
f_3	-0.1158 (-1.416)	-0.0797 (-1.065)	-0.0119 (-0.170)	0.0488 (0.986)	-0.1350 (-1.872)	-0.0522 (-0.700)	-0.0940[b] (-2.163)

Note: a. significant at .01 level; b. significant at .05 level; c. significant at .10 level
e. parameters constrained to be equal to zero
Figures within parentheses are t-values
Model A: Input-Output Separability, Model B: Gobal Separability,
Model C: Homogeneity, Model D: Non-jointness-in-inputs production, Model E: Equality of common parameters between profit function and share equations (Profit Maximization).

Hypothesis Tests

The restriction that parameters of the share equations are the same as those of the restricted profit function is essentially to test as to whether the fishing firms are profit maximizer (model E, table 1). The relevant econometric restrictions for the equality of common parameters between the profit function and the share equations is $\alpha_i=\Theta_i$, and $\alpha_{ij}=\Theta_{ij}$ (i and j are respectively output and input, α and Θ are parameters of the restricted profit function and share equations). The econometric restriction did not appear to be valid indicating that the gillnet fishing firms operating in the underlying common property fishery cannot maximize profit(Table 2). This appears consistent with the resource use principle under common property regime where the use and entry of firms are not restricted. Fishermen, being rational human being, do have the motive of maximizing profit like farmers in agricultural enterprises. Gordon (1954) goes by saying that fishing firms acting as perfectly rational profit maximizers drive the fishery to what is known as bioeconomic equilibrium where rent is dissipated. This stems from the fact that common property nature of the resources and the interaction of different firms subsequently entered into the fishery make them behave in a manner that pushes their fishing effort beyond the profit maximizing point.

The non-profit maximizing behaviour is a natural consequence of open-access fishery. The existing state of resource use leads to excess effort, biological overfishing and dissipation of economic surplus[8]. These remind that proper regulatory technique should be called for in order to alter the production behaviour of the fishermen and improve the potential of fishery.

Input output separability (Model A) requiring no specific interaction between variable inputs and outputs (Latinen, 1980) has been tested by putting econometric restriction $\alpha_{ij}=0$, $i\neq j$, (i= output species and j= variable inputs). The F-statistics was found to be 0.19 indicating that the null hypothesis could not be rejected. This implies the existence of the highest level of aggregation i.e., a single composite output and input which bioeconomic models traditionally maintain. The acceptance of the input-output separability provides empirical support that aggregation of inputs (outputs) in the form of a single composite fishing effort (output) can be made for the gillnet.

Table 2. Results of the Hypotheses Test for the Gillnet Firms.

Hypotheses	SSE	Num. d.f	Den. d.f	Calculated F-Value	Critical F .05	.01	Decision
1. Unrestricted Model:	147.30						
2. Input-output Separability:	149.12	10	151	0.19	1.89	2.44	Accept H_0
3. Global Separability:	201.34	21	151	2.64	1.63	1.98	Reject H_0
4. Homogeneity in Prices:	153.98	7	151	0.60	2.07	2.76	Accept H_0
5. Non-jointness in inputs:	151.25	3	151	1.35	2.67	3.91	Accept H_0
6. Profit Maximization:	333.00	29	151	6.56	1.54	1.83	Reject H_0

The consideration of jointness-in-inputs production in a multispecies fishery having far reaching implications for single stock management was tested using the econometric restriction $\alpha_{ij} = -\alpha_i.\alpha_j$, i(j) are outputs, $i \neq j$ (Model D). The F-statistics shown in Table 2 for the test of nonjointness suggest that the hypothesis could not be rejected. The acceptance of non-jointness in inputs production for the gillnet technology implies that separate production function exists for different species vulnerable to gillnet technology. This suggests that output of any single process then depends only on the inputs used in that process and not on the level of inputs or outputs in any other production process. Each production process can thus be separately maintained and regulated without affecting the production of the other processes because there are no technological or cost tradeoffs between the output of one activity and that of another. It is possible to allocate the overall fishing effort between the constituent species of the stock when a partial nondiscriminatory gear like the gillnet is applied to a multispecies fishery because of the non-existence of technological interactions among species. This implies that management regulations that affect vulnerable species can be maintained for the gillnet technology. It is then possible to save a stock through species regulation which is in the process of extinction.

Partial elasticities

Elasticities of supply of, the three aggregated species are all insignificant and inelastic (Table 3). As the elasticity estimates are insignificant, it matters little as to whether the algebraic signs are positive or negative. While positive signs are expected negative sometimes may appear because of specification bias for probable exclusion of the biological variables related to the gillnet production technology, presence of a number of insignificant dummy variables and bias due to output aggregation (see, for example, Gates, 1974; Kirkly and Strand, 1988; and squires, 1987).

Elasticities of input demand are significant with appropriate negative algebraic signs. The magnitudes are 0.2378 for energy consumption and 1.7772 for crew/labour. The labour demand is price elastic while energy consumption is inelastic.

The inelastic nature of the energy consumption determines the importance of fuel/energy in gillnet fishing.

Cross price output supply elasticities of all the aggregated species are positive of which majority are significant at 0.01 level of probability. The positive signs indicate that the aggregated species are complementary to each other. As the magnitudes of cross price supply elasticities are less than one they appear to be inelastic. As far as cross input demand elasticity is concerned the demand-price relationships, as evidenced by the standard errors, are significant. The two variable inputs appear to be complementary to each other indicating that the two inputs are of equal importance in producing catch under the existing state of technology.

Supplies of output are significantly adversely affected if the price of crew/labour goes up which is not so in case of price of energy/fuel. Demand

Table 3. Elasticity Estimates for the Gillnet Firms.

Relattions	High Grade (A) Species	Medium Grade (B) Species	Low Grade (C) Species	Energy Consumption	Crew/ Labour
High Grade (A) Species	.1729	.1065	.6778[a]	-.1079	-.4612[a]
	(.1780)	(.2787)	(.1388)	(.1734)	(.0762)
Medium Grade (B) Species	.3206[a]	-.0431	.3877[a]	-.2025	-.3381[a]
	(.0926)	(.4536)	(.1194)	(.2292)	(.0385)
Low Grade (C) Species	.5723[a]	.1718	.1849	-.1024	-.9196[a]
	(.1644)	(.4255)	(.1910)	(.2279)	(.0361)
Energy Consumption	1.0971[a]	.1922	1.3353[a]	-.2378[b]	-.6928[a]
	(.0316)	(.1269)	(.0351)	(.1142)	(.0105)
Crew/ Labour	1.2820[a]	.4635[a]	1.0533[a]	-.1098[a]	-1.7772[a]
	(.0876)	(.1333)	(.0350)	(.0662)	(.1360)

Note: Figures within parentheses are estimated standard errors
a. Singnificant at .01 level
b. Significant at .05 level
c. Significant at .10 level

for inputs exhibited positive response with the increase in output prices. All of the input demand elasticities are significant except one. This is quite likely as firms find it rational to add more of fishing inputs in order to make effective fishing as long as markets consume the produce/supply.

V. CONCLUSIONS AND IMPLICATIONS

The paper aimed at investigating into the production technology of the gillnet fishing. By using the duality theory, a translog multiproduct profit function was applied to study the production relationship between outputs and inputs. As far as the characteristics of the gillnet fishing technology is concerned, the production is non-joint in inputs and the input-output relationships are separable indicating that separate production function exists for each of the aggregated output species. Since the existence of different production function is apparent for the gilllnet catch, it is possible to restrict fishing effort through species regulation and save species of interest from extinction. Supplies of fish are, in general, not responsive to changes in prices. This suggests that supply adjustment cannot be made by manipulating output prices at the present state of technology. Further technological development is necessary in order to make fishermen price responsive. Input demand, however, is quite responsive to changes in their prices. Relationship among different species are complementary. Complementarity also exists between variable inputs i.e., between energy and labour/crew indicating that both are necessary in the present level of gillnet fishing. The production behaviour appears to be consistent with the nature of the common property resource. The gillnet fishermen turn out to be non-profit maximizer.

Notes

1. Fishing effort is a composite index of input often aggregated from component elements such as, capital, labour, materials and time spent in fishing. Bio-economic modelers often use the term for studying catch and effort relationship in fishery.

2. Under common property regime, there is free and open access to the fishery allowing simultaneous use of the resources for those interested. The condition of free and open access is often accompanied by detrimental economic consequences to the fishery resources whenever it occurs (see, Anderson, 1986 for adequate explanation).

3. Department of Fishery, Malaysia provides three different gradings, namely, grade-A, grade-B, and grade-C species depending upon the high, medium and low prices of the species. Prawn of different species constitutes a separate grade.

4. Unlike in agriculture, the labour/crewmen employed in capture fishery are not paid wage. Rather, they are remunerated on the basis of share of catch. The usual practice is to deduct the operating cost from the gross revenue and divide the net between the boat owner and the crewmen on the basis of a predetermined proportions. The total share of the crewmen are then distributed among the different heads depending on the nature of work assignment (see, Alam, 1991 for details of the mechanism of sharing the the income of marine fishermen).

5. The advent of the flexible functional form allows examination of a large number of economic effects and fewer hypotheses to be maintained on the structure of the

technology and on the elasticities of substitutions and transformations. A flexible functional form can be considered as either a true or an exact function in its own right, or as a linear-in-parameters second order approximation to an arbitrary, twice differentiable function at any chosen point.

6. Length, breadth and depth representation of the boats. When measured in meter, the gross registered tonnage (GRT) is expressed as length times breadth times depth times 0.2826.

7. Estimated parameters of model E forms the basis of elasticity estimates as the model contains the restriction relating to the profit maximizing behavoiur of the fishing firms.

8. This happens because of the fact that investment decisions are made on over optimistic forecasts of yield based either on proportional extrapolation of past yields or on exceptionally good fishing year. Since fishermen make their investment decisions quite independently from each other and since the economic life of a vessel is quite long, over-investment is very likely. Moreover, once built, a fishing vessel is, to a large degree, a 'sunk' cost and would keep operating whether it covers its fixed cost or not, as long as it covers its operating costs. Another reason for the expansion and sustenance of effort beyond the bio-economic equilibrium with consequent negative resource rents is the tendency of government to subsidize (directly or indirectly) the industry thereby lowering the private cost of fishing below its true social costs. Finally, fishermen may be earning incomes below their opportunity costs because of geographical and occupational immobility (See, Panayotou, 1982 for a detail discussion).

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