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This study develops an improved method for understanding economic production relationships in small scale fisheries. This method postulates that gross revenue is a function of physical input quantities, and is based upon the transcendental logarithmic function to derive factor share equations for each of the five inputs in the model. The translog form was selected because of its flexibility, non-constant elasticity of substitution, and input interaction to give a more realistic representation of production relationships in small scale fisheries. The model was tested using cross-sectional data from a cost and earning survey on the Florida reef fishery. The joint generalized least squares procedure for seemingly uncorrelated equations was used for the parameters estimation. A total of 68 observations were used. The estimation results were not very encouraging because of the poor

response of the model. This may in part be attributable to inconsistencies shown by the data.

The translog gross revenue function, was also estimated. The result showed good response. However, the model was characterized by multicollinearity and sensitivity of parameters to variable substitution. Similar results and characteristics were obtained when the Cobb-Douglas function was estimated. These results were also influenced by the size and the characteristics of the data set.

The method presented here for estimating economic production relationships in small scale fisheries is attractive because (1) factor share and output elasticities are a function of the inputs and (2) it allows varying the inputs in bundles instead of individually, which is more realistic for policy analysis. Further testing of this model is encouraged using a larger and more accurate data set.

Estimation of Small Scale Fishery Production Relationships: The Case of the Florida Reef Fishery

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A mi esposa, Odette,

y a mis hijos, Andres

y Alejandro.

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CHAPTER I

INTRODUCTION

Small scale fisheries are composed of those fishing firms which have limited economic and technological options available to them and are characterized by labor intensiveness.

Small scale fisheries represent, especially for developing countries, a valuable socio-economic alternative for providing job opportunities and proteins for human consumption. Small scale fishermen constitute aproximately 95 percent of the world labor engaged in fishing, supplying more than 50 percent of the fish for human consumption at high rates of catch per fuel ton expended (Lawson, 1984).

National governments, with the cooperation of international agencies for fisheries development, have intensified efforts to develop small scale fisheries after the adoption of the 200 mile economic exclusive zone by most coastal nations in 1977. Common objectives for the development of small scale fisheries are: to increase the supply and demand of fish; to increase fishermen income; and to create more job opportunities in the fishery. To achieve these objectives, special loans and technology transfer programs are usually made available to fishermen.

However, there are questions concerning (1) what resources to allocate and (2) how these resources should be allocated to small scale fishermen. These questions are critical to the success of any development program. In this respect, Sutinen and Pollnac (1981) express that "to successfully address the fisheries development problem, one must first solve the associated implicit information system problem". This implies that making decisions for fisheries development requires information. This information consists of a system where data is collected, analyzed, and communicated to decision makers. This information system can then provide an understanding of the different components of the fishery, e.g. how the fish resource, catch production, fish markets, and institutional and socio-cultural factors interact and what the causal relationships of these interactions are. These relationships are not usually well known in small scale fisheries.

This research is concerned with causal production relationships in a small scale fishery. Production relationships include a description of how one or more inputs (or production factors) are related to output (catch) in a given production process. There are in this process several possible input combinations, each yielding a discreet output level. This is usually referred to as the production possiblity set of the firm. If output is produced with technical efficiency (i.e., maximizing the output for every possible input combination), the production relationship is referred to as the production function. Therefore, the production function is the mathematical representation that states the maximum output attainable from a specified set of inputs. In this sense, the production function is a technical relationship. However, if the best input combination is selected according to output and input prices, then outputs are produced with economic efficiency.

Studies of production relationships in fisheries are conducted for two purposes: (1) for managing the fish stocks and (2) for allocating resources in the fishery. The first is mainly concerned with the development of biologically oriented models describing relationships between catch and fishing effort for purposes of determining fish stock abundance and proposing biological fishery regulation measures. Economists, in their efforts to integrate biology and economics, use the same kind of models for discussing theoretical issues regarding economic efficiency of the fishery under exploitation. For this purpose prices of the catch and fishing effort are included in the model. Agnello and Anderson (1981) provide an example of an economic empirical application of the biological production function. They studied production relationships in the North Atlantic groundfish fishery by combining economic inputs into a single input, the fishing effort. In other words, a production function subject to economic analysis was modified to fit the biological requirements of the fishery production function without losing the economic interpretation.

The second aspect is concerned with model construction and estimation for economic analysis of the production process; in this case, with reference to small scale fisheries. Beyond the production possibility set obtained from the estimation of a production function, where physical units of labor, capital and materials are the inputs, the model also gives information about the marginal contribution of each input to the catch and the proportionate catch variation when all inputs changes in the same proportion. However, the production function, when combined with input and output prices, provides economically meaningful information. For example, if gross revenue is a function of inputs, it is possible to estimate the marginal contribution of each input to the total revenue and the proportionate revenue variation when all inputs change by the same proportion. Furthermore, since labor share in each firm is a proportion of total boat revenue, it is possible to compute the differences in fishermen's income between boats. If profit maximization for the fishing firm is assumed, then the value of the last output unit produced compared to the input price gives valuable information about the economic efficiency of the production process. Profit differentials between sets of inputs can also be estimated. This is of particular importance for management policies. Normally the profit in fisheries contains elements of returns to fixed inputs (the capital rent) and to the fish resource (the resource rent) if the fish population is exploited under a common property regime. In short, estimating production relationships in small scale fisheries will provide some basic information to decision makers for devising policies and programs to manage and develop the fishery. Also, the estimated production function for individual firms may be used as a reference to compare and/or adjust the production process to achieve an efficient level of operation.

Two main problems are normally associated with the estimation of production relationships in small scale fisheries: First, studies attempting to estimate production relationships are scarce, consequently, only few examples exist in the literature of fisheries economics. This limits the experience with methodology especially in connection with model formulation and variable selection. Nevertheless, most empirical applications have derived production relationships based upon a biological model of production. Use of such a model seems reasonable because man acts as another predator on the fish populations. Examples are studies by Comitini and Huang (1967), Huang and Lee (1976), Agnello and Anderson (1977), Bell (1972), Hussen and Sutinen (1981), and Panayotou (1985). The last three of these studies are applications to small scale fisheries.

The second and most serious problem associated with estimation of production relationships in small scale fisheries is the lack of adequate and reliable information about the production process. Small scale fishermen do not usually keep records of the performance of their fishing firms. If they do, their records are often incomplete and inaccurate for use in research. To offset this problem, researchers generate real-world data using two types of survey procedures: making controlled observations of selected fishing boats over a period of time or questioning fishermen on their past production actions over a period of time. Controlled observations give more accurate and real information but they are more expensive to obtain and lengthen the research process. Obtaining data on past actions is more frequently done. Although less expensive, this second approach is also less reliable because fishermen have to recall past events when responding to survey questions. In the absence of accurate and timely information, economists working in small scale fisheries research seem to be confined to do the best with whatever information is available.

According to the preceding discussion, the general objective of this research is to describe an improved method for estimating economic relationships of production in a small scale fishery.

The specific objectives are: (a) to describe a model to estimate revenue shares of factors of production based upon the neoclassical theory of the firm; and (b) to estimate the model parameters using a given set of cross-sectional data, which corresponds to a cost and earnings survey conducted on the Florida reef fishery by the National Marine Fisheries Service in 1981.

Revenue factor shares, and distribution issues in general, are important to evaluate the impact of varying inputs of production and/or fisheries regulations on the economic performance of the fishing firms. For example, revenue factor shares show input expenditure/revenue ratios. Changes in the expenditure/revenue ratios results from implementation of subsidy and tax programs. This is an externally imposed redistribution of cost. The model presented here is a first attempt for explaining this type of relationship in the production of small scale fisheries. Results are limited to the particular set of data available. However, the distribution problem is of common interest in production of small scale fisheries. The methodology developed here is applicable to other small scale fisheries and can also be expanded to the aggregate level of fisheries.

CHAPTER II

THE PRODUCTION FUNCTION OF A FISHERY

The Theory of Fisheries Production Function

The production process in a fishery is merely the transformation of part of the fish population into catch. The economic interpretation of the process is that a common property resource is transformed into a possessed one, which can provide private economic benefit. In so doing, a certain fishing effort is applied to a fish population. Therefore, the production function for the fishery can be described as the relationship between the output, the catch, and the inputs, fish biomass and fishing effort. This relationship is commonly known as the Schaefer model. It is the theoretical basis upon which most economic analysis in fisheries production is based.

The Shaefer model postulates that in equilibrium the amount of catch is a function of the fishing effort alone. The following presentation of the Shaefer model follows the description made by Anderson (1977) and Clark (1976).

The net growth of an unexploited fish population is a function of its size. Given constant environmental conditions, this unexploited fish biomass will grow at an increasing rate for low population levels. At a certain population level the growth rate starts decreasing and becomes zero at the level of its maximum biomass. This point at the saturation level of the environment or the carrying capacity of the environment, is the population equilibrium size. dB/dt, the growth of the fish population with respect to a time period, t, will then be:

$$dB/dt = F(B) \qquad (1)$$

where the instantaneous growth rate is a function of the biomass, B. In theory, it is generally assumed that the growth rate is a decreasing function of the biomass, B.

The growth rate is a net proportional growth rate, where summation of individual fish weight increment plus recruitment is compensated for by natural mortality of the population. The graphic representation of the growth rate curve for different biomass takes the form of a bell-shaped curve.

When harvesting takes place, the biomass will move into a new equilibrium as the net natural increase of the fish population is compensated by harvesting. This is:

$$dB/dt = F(B) - Q_t \qquad (2)$$

where Q(t) is the instantaneous harvesting rate as a function of the fish biomass and the amount of fishing effort, E, exerted on it:

$$Q_t = g(B,E) \qquad (3)$$

Fishing effort is an index traditionally defined as fishing time multiplied by the fishing power of the vessel. Fishing power is estimated as the ratio between the catch of a vessel to the catch of a standard vessel when both are fishing simultaneously on the same ground.

If the population is in equilibrium, then the catch rate equals the natural net growth of the biomass for any level. Furthermore, if equilibrium exists for each of these population sizes, there will be a one-to-one correspondence between the fish population size and the level of fishing effort. Under this equilibrium condition, the level of fish biomass, B, is a decreasing function of the fishing effort, E. That is:

$$B = b(E) \qquad (4)$$

Hence, equation (4) implies that in equilibrium, the maximum possible catch to be taken per unit of time is a function of the amount of fishing effort alone; that is:

$$Q_t = q(E) \qquad (5)$$

Equation (5) is the Shaefer model representing the long-run production function of a fishery or, according to the biologist's concept for population dynamic analysis, the well-known sustainable yield curve. The theoretical sustainable yield curve is shown in Figure 1.

The Shaefer model is a very simplified version of reality. Most problems in fisheries are of a stochastic nature and not deterministic as is the model described.

a)

b)

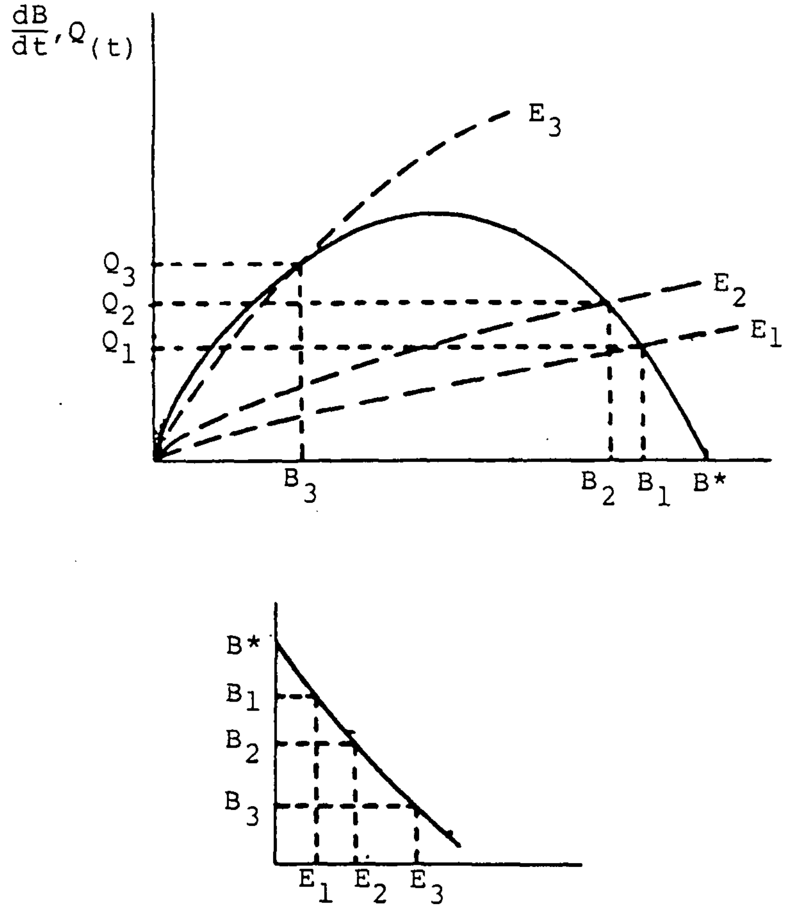

Figure 1. Theoretical Equilibrium in a Commercial Fisheries (from Anderson, 1977).

a) The sustainable yield curve: the catch rate is equal to the growth rate of the B<u>th</u> equilibrium population for the E<u>th</u> level of effort.

b) Relationship between population size (B) and fishing effort (E).

For example, the Shaefer model does not describe other aspects such as seasonal patterns, age, and size structure of the fish population and multispecies stocks; although they are assumed to be implicit in such a model. However, the Shaefer model is a useful theoretical tool for discussing the economic aspects of the fishery production function.

Revising the Theory

It is expected that in the long run the production function in any fishery shows diminishing marginal return to the fishing effort and also decreasing returns to scale in the relevant stage of production, if the function is continuous with first and second derivatives.

However, using a single variable as the index of fishing effort to describe product/factor relationships in fisheries presents some problems. Fishing effort is primarily a technical unit conceived as a tool for measuring the impact of catch on fishing mortality and to relate it to the size of the fish biomass. Consequently, it is an aggregate index that internally combines factors of production, e.g. capital and labor, into units of equal production capacity. It assumes fixed proportions of inputs for the same relative fishing power.

This is not the general case in fisheries. The most likely case is that of different ratios in the internal composition of the fishing effort. This is not captured in the single index variable used in evaluating the biological production function. Even for stock assessment purposes, the assumption of mixed input proportions presents some difficulties for similar reasons.

It is known that in a common property fishery resource two types of externalities are likely to occur: (a) the resource stock externality, which is the reduction in fish population size and age structure with the increment of fishing effort and (b) the crowding out externality, which is the congestion caused by an excess of fishing vessels or gears on a particular fishing ground. Both externalities lead to a decreasing catch per unit of effort.

Changes in both fishing strategies and technology are realized as a result of either externality. These may include changes in the amount of fishing gear and/or fishing time on a ground; improving the deck machinery or electronics, so that more tows per period of time or a more efficient search for fish are achieved; modifying vessel designs to reach more distant fishing grounds,etc.

Theoretically, in the case of aggregate inputs the fishery production function would require that the rate of technical substitution between factors, e.g. capital and labor, be independent of the changes in the fish stock (Huang and Lee, 1976), which is the interpretation of the Leontief theorem on separable functions. This is quite unlikely to be true considering the preceeding comments;

so that, a single variable index of fishing effort is not a strong argument for the production function.

Variation in the internal composition of the fishing effort also may occur due to the behaviour adopted by fishermen. Fishing effort is a variable controlled by fishermen and it can be expected that its size and distribution will depend on output and factor prices as a consequence of an optimizing behavior. For instance, profit maximizing or cost minimizing behavior and risk aversion or risk taking behavior will lead to different decisions regarding the size and distribution of the effort. However, prices are more likely to affect short-run decisions rather than the long-run decisions. These are noticeable in the selection of species to catch, fishing grounds and fishing strategies.

The preceding illustrates in a rather simplistic manner the reasons for observing the production function of a fishery with the input index of fishing effort disaggregated. The function can be subjected to more precise economic analysis which would allow for the estimate of a production possibility set showing all possible production plans or the production surface for all input combinations in the relevant region of production, assuming that fishermen behave rationally. Substitutability between inputs is then possible whereas it is not in the single variable case. Alternative economically efficient production plans may then be observed.

The discussion up to this point has been concentrated at the aggregate level of a fishery. Nevertheless, the same concepts apply to individual firms operating in the fishery, whether in the short or the long run. Furthermore, presenting the aggregate theory of fisheries production for individual firm model analysis helps to understand: (a) the nature of different input combinations used by individual firms; that is, the different ways that individual fishing firms cope with externalities or react to price changes; and (b) equilibrium and dynamic situations in the fisheries for specification and interpretation of economic models built with realistic assumptions.

In summary, then, under equilibrium conditions the catch is a function of the fishing effort alone. The fishing effort is an aggregate input, whose economic interpretation is meaningless; therefore, fishing effort must be decomposed into units of capital, labor, and materials. It is also expected that at aggregate as well as individual firm levels, the production function shows diminishing marginal productivity.

CHAPTER III

PRODUCTION STUDIES ON SMALL SCALE FISHERIES

The Small Scale Fisheries

The existence of a division in the fishery sector is widely recognized: the small scale or artisanal fisheries and the large scale or industrial fisheries (Panayotou, 1982). The distinction between the two is almost exclusively associated with different strategies of development and objectives of management. In connection with small scale fisheries, development programs usually comprise subsidized loans and technical training in order to locally promote or increase employment and provide protein for human consumption.

The characteristics of small scale fisheries vary among countries or regions. Panayotou (1982) refers to small scale fisheries as "those who have limited fishing range, are confined to a narrow strip of land and sea around their community, face a limited set of options and are intrinsically dependent on the local resources." In contrast, "those who have a broad spectrum of options in terms of fishing grounds and nonfishing investment opportunities" constitute the large scale fisheries.

This is a very broad mutually exclusive description of the two fisheries. Although it provides a reference to separate two socio-economic groups, it does not provide any insight into their production processes. It may also be restrictive in the sense that it applies only to fisheries in developing countries.

In small scale fisheries fish production, processing, distribution, and marketing are commonly decentralized processes. Fishermen are mostly involved in production of fish, an activity that is characterized by being labor intensive, with low ratios of capital to labor.

This characteristic implies several aspects that help to understand the production process in most small scale fisheries. First, there exist a large number of fishing boats of small and medium size, each constituting an individual economic unit or fishing firm. Second, fishing gear methods are not characterized by massive catches but usually by being selective in terms of species and species size sought. Common fishing gear in use are hook and lines, gill nets and fishing traps and pots. Vessel technology is quite variable; in fisheries of developing countries automation of fishing operations and electronics for directing fishing and navigation are unusual, whereas they are common in developed countries. Third, options for selecting fishing grounds are limited by boat size and technology; smaller boats are restricted to fishing areas close to the location of the fishing community. However, options increase with improvement of technology on fishing boats.

Investment opportunities in other than the fisherman's own fishing firm are very unlikely. Access to the regular financial market is available, but limited. Therefore, financial services are usually provided by fish traders.

In most situations, small scale fisheries operate with free access to fisheries resources. Stock externalities may be negligible for some operating under this condition because of fishing gear selectivity. However, congestion externalities may exist. In other cases where the fishery is composed of low or nonmigratory fish populations, congestion externalities may not exist; e.g., the case of the Maine lobster fishery where fishermen have by themselves assigned fishing territories (Acheson, 1982). On the other hand, stock externalities are sometimes imposed by large scale fisheries on small scale fisheries. This is the case where both fisheries compete for the same resource, even though they both operate over different fishing grounds. Large scale fisheries tend to intercept a fraction of the fish population before it migrates to the fishing grounds accessible to small scale fishermen.

The production process is described by the way fishermen distribute fishing effort over time and space. The simplest production process, although not common, is when fishing effort is directed over one single species throughout the year. The fishing method used is highly selective in terms of species type. This is a single output process, and fishermen become highly specialized.

A second situation can be described as multipurpose fishing when fishermen seasonally alternate the species sought using a certain selective fishing gear. The production process is then consistent with the description of a separable multi-output/multi-input production function where factors are explicitly allocated to specific outputs.

A third situation is the case of joint production, where technological interdependence exists, i.e., when effort exerted over a particular species produces, with the same fishing gear, a by-catch, e.g., nontargeted species are simultaneously caught. The relative amount of by-catch is related to the fish population distribution and composition over the fishing area. In joint production, allocation of inputs to specific outputs are not possible.

The three types of production processes described are likely to be observed in small scale fisheries, but joint production is the most commonly observed among the three. Table 1 summarizes the three types of production processes.

Production Studies on Small Scale Fisheries

Economic studies of small scale fisheries are common, but only a few are predictive in nature. Most depict a current situation of the fishery, using mainly cost and earnings studies of representative types

Table 1. Characterization of the Different Types of Production Processes in Small Scale Fisheries.

Type of Production	Output	Gear Technology	Types of Production in a Year
Single	Single	Single	Mono period
Multi-purpose	Multiple	Multiple	Multiple
Joint	Multiple	Single or Multiple	Mono or multiple

of firms in the fishery. These tend to be very comprehensive and several include an analysis by main species caught, gear type, and/or boat type.

Examples of complete studies of small scale fisheries are the cost, earnings, and profitability analyses of Alaska fishing businesses (Smith et al., 1975), and the cost, returns, and profitability analysis of small scale fisheries in the Philippines (Smith and Mines, 1982), and in several countries in Southeast Asia (Panayotou, 1985). The Smith and Mines and Panayotou studies also reported on estimations of resource rents and their implications for the management of those fisheries. In addition, all three studies included statistical analysis of production relationships in an attempt to predict production and/or revenue responses of fishing units in the fishery.

Among other available studies, specifically on production relationships in small scale fisheries are those developed by Comitini and Huang (1967) in the halibut fishery, Bell (1972) in the northern lobster in United States, and Hussen and Sutinen (1981) in the artisanal fishery of the Gulf of Nicoya in Costa Rica.

Cross-sectional data collected through random samples has been used in all these studies with the exception of that on the halibut fishing industry which combined cross-sectional with time-series data. Cross-sectional data has the advantage that it may overcome the problem of changes in technology as data cover only one period in the time space; types of inputs and their quality are assumed fixed for the period observed. Also, it allows some degree of substitutability among inputs. For estimation of fisheries production functions using cross-sectional data, fish biomass is assumed constant for the period under study.

Data are collected through either questionnaires that usually seek yearly information per fishing unit or surveys recording daily information during a period, usually a year. This last procedure produces more exact and rigorous information but at a high cost whereas the opposite is true for the former method. Samples in either case have been randomly selected; this procedure may bias the number of observations with respect to relevant sections of the response surface in the production possibility set because samples can be concentrated more heavily in some subsets of such a set. Random sampling might be a problem when fleets are not homogeneous or when production relationships aggregate geographic locations and/or fisheries. In these situations, combination of randomly selected and stratified samples are advisable.

Functional Forms Used in Previous Studies

The selected functional form in most of the previous production studies in small scale fisheries is the homogeneous Cobb-Douglas type, whose general form is:

$$Q = Ax_1^{\beta_1} x_2^{\beta_2} \cdots x_n^{\beta_n} \qquad (6)$$

where the exponent β_i represents the elasticity of production the $i^{\underline{th}}$ input. The sum of the exponents is equal to the function coefficient which gives information about returns to scale; that is, the function presents decreasing, constant or increasing returns to scale if the summation of β's is less than, equal or greater than 1, respectively. The Cobb-Douglas formulation also imposes a constant factor elasticity of substitution equal to one.

Bell (1972) used the following functional form for describing the production function of the northern lobster fishery:

$$Q_t = k\,N^*\,E_t - \left(\frac{k^2}{a}\right) E_t + \frac{kU_t}{a}\,E_t + U \qquad (7)$$

where

Q_t = catch per unit of time

N^* = maximum lobster population or population at salvation level

E_t = fishing effort (number of fishing traps) composed of labor and capital per unit of time

U = error term

a,k = parameters.

This model was estimated using time-series data, assuming that the capital and labor inputs were combined in fixed proportions.

Dividing equation (7) by E_t, Bell was able to show how the catch per unit of effort, Q_t/E_t, varies with the number of fishing traps used during the fishing period. In other words, the model showed the effect of the stock externality.

Khaled (1985) estimated production relationships in the riverine fisheries of Bangladesh using the following functional form, a modification of the translog function:

$$\ln Q = C_0 + A \ln X_3 + \sum_{h=1}^{2} C_h \ln (X_i/X_3) + \sum_{k=3}^{5} C_k \ln (X_i/X_j) + \sum_{l=6}^{7} d_l X_e \qquad (8)$$

where:

Q = catch weight

X_1 = labor in man-days

X_2 = boat tonnage

X_3 = weight of fishing net

The model was estimated using cross-sectional data. In addition, Khaled estimated the partial elasticities of substitution using the bordered Hessian derived from the production function.

Variables Used in Previous Studies

In cases where the production process in fisheries is of either single of multi-purpose type, the explanatory variable is expressed in physical quantities, e.g., catch volume or number of fish.

In the multi-output (multispecies) joint fishery production process the production function is not separable. Therefore the output is expressed as some weighted index such as gross revenues; that is, a summation of the product of physical outputs time its price, under the assumption that prices are constant. Therefore, the function relates one single output to multi-physical inputs. In this case, the function is a gross revenue function (or total value product, or total revenue product function) whose explanatory variables are physical input quantities. Some examples of this type of function in small scale fisheries are provided by Hussen and Sutinen (1981), Tokrisna et al. (1985), and Frederiks and Nair (1985).

Closer attention to the explanatory variables used in estimation of production relationships is needed. Economic production and gross revenue functions must include explanatory variables that can have economic interpretations and applications. Estimations made in small scale fisheries usually include variables to which it is difficult to assign economic values. These types of variables are included especially in cross-sectional studies to avoid hybridity, i.e. the effect produced on the estimated when significant variable inputs are omitted. Length of the net, mesh size, weight of the net, fishermen's age and experience, age of the vessel or fishing time are common variables specified in fisheries production functions. Although they may significantly contribute to the explanation of output responses their economic value is difficult (if not impossible) to obtain.

Fishing time, which could be number of fishing trips per season or number of fishing days or weeks per season, has been found to be statistically significant in predicting production relationships in small scale fisheries. For instance, Smith et al. (1975) found that the number of fishing weeks was the most significant variable in the gillnet and troller salmon fishery of Alaska; Hussen and Sutinen (1981) reported that number of fishing days was significant at .01 level in the hook and line and gillnet fishery in Costa Rica; Yater (1985) reported higher significance when using the number of trips to explain variation in total revenue in the gillnet fishery in the Philippines. Although the cost of fishing time is not directly observable, it can be estimated by assigning to it some of the operating expenditures incurred by the firm in the production process.

The use of boat characteristics as an index of capital also requires further comments. The most common indexes are boat length, tonnage of the boat, engine horse power and hold capacity; choosing one or more of these as explanatory variables depends on the type of fishing technology and/or the geographic location as these influence the structural design and equipment selection of the fishing vessels.

For example, Carlsson (1973) found that hold capacity was quite significant in describing production relationships of the tropical purse seine fishery. He also found that gross tonnage and engine horse power were significant in the trawl fishery of the North Atlantic. Smith et al. (1975) found that engine horse power was statistically significant in some geographic areas in the Alaskan small scale fisheries. Tonnage and engine horse power were found significant in small scale fisheries of Thailand (Trokrisma et al., 1985), and of Malaysia (Fredericks and Nair, 1985), respectively.

Another proxy for capital inputs is an index based on the current market value of the boat. However, market prices for fishing boats are neither easy to obtain nor to estimate. An alternative index could be constructed using boat values reported by fishermen and boat owners. This is an expected price, which may show discrepancies with market prices because fishermen tend to include the present value of net revenues anticipated over time in their estimation of the expected price of the asset.

As an alternative to the market price of the asset, the initial cost plus the additional investment minus the cost of the capital consumed (or depreciation) can be used as a proxy. There are two main approaches used for estimating depreciation. One is for taxation purposes, which is not particularly useful for economic analysis. The other is the technical approach, which depends on two factors: (a) the actual physical wear of the asset, depending on its use and maintenance; and (b) the loss of production efficiency (technological obsolescence), normally induced by the competition in the fishery.

In summary, most production studies in small scale fisheries have focused on explaining the physical production processes; that is, they have emphasized technical relationships. Their compatibility with the economics of firms has not been shown; and the functional forms used have been restricted to the most common, such as the Cobb-Douglas type. Other forms such as the quadratic types and constant elasticity of substitution have only occasionally been used. The independent variables used in previous studies have also tended to emphasize technical production relationships. However, most studies have shown that fishing time and certain boat characteristics, e.g., boat capacity, boat length, or engine horse power, are significant. Which one of these boat characteristics is used as an index of capital depends on the fishing method used in the fishery. With respect to dependent variables, only when single or multi-purpose production processes occur is it possible to use physical quantities (catch). In the case of joint production, the output is usually expressed in total money income, and the function becomes a gross revenue function.

CHAPTER IV

MODEL SPECIFICATION AND ESTIMATION

Specification of the Theoretical Model

It is convenient to recall here the two main problems limiting the study of economic production relationships in small scale fisheries: (1) the lack of previous studies on the subject and (2) the lack of adequate data. These limitations are important to the study of production relationships, especially when the objectives are to find better methods of estimating these relationships.

In specifying a model for describing the production process it is necessary to consider the steps related to specification of the economic hypothesis, data collection and econometric analysis. Each of these steps is interrelated with the others.

Decisions in model specifications are related to (1) the number of equations in the model; and (2) selection of variables -- the dependent variable, or output and the independent variable, or inputs. Variable selection depends on the production process modelled and the availability of data. The selection of variables may affect the econometric analysis through specification bias with variables originally choosen. On the other hand, the functional form(s) of the model will depend on the economic restrictions imposed or assumptions made about the production process. This section will treat only the variable selection and number of equations required.

The present analysis will focus on the reef fishery off the Florida coast. The fishery exhibits those characteristics common to small scale fisheries such as non-capital intensive, simple and selective fishing gear technology and non-restricted access to the fishery. Fishing effort is directed to species such as snapper, grouper and similar fish; the fishing operation is dominated by technological interdependence which characterizes the case of a joint production process.

The data for this study have been provided by the Southeast Fisheries Center, National Marine Fisheries Service. It corresponds to a cross-section survey on cost and earnings made in 1981 on vessels operating in reef fishing off the Gulf of Mexico and South Atlantic coasts.

Information from both the survey final report (Nero and Associates, 1981) and the data itself suggest that:

(a) The survey procedure was conducted by individual interviews of vessel owners or fishermen randomly selected after stratifying the population into two geographic areas.

(b) The data contain information on capital description and values, fishing effort (fishing time, gear per trip and fishing ground), crew share system, fixed and variable cost for one fishing season and catch and revenues. The questionnaire used to collect the information is illustrated in Appendix A.

(c) The size of the sample was 64 vessels out of a population of 402 in the Gulf of Mexico and 26 out of 151 vessels in the South Atlantic coast. In addition, the population was stratified by hull length, (small and large), in each of the two areas.

(d) Vessels varied in length from 25 to 73 feet, but the fleet was homogeneous with respect to engine type and electronic equipment.

(e) The major fishing gear was hook and line; differences were noted if hooks were mounted on individual versus long lines and if lines were handled manually versus reels.

From Equation (3) it is known that catch is a function of the fish population and fishing effort. Because the data are cross-sectional, the fish biomass is assumed to be constant for the period under observation (one fishing season). Furthermore, if it is assumed that the fish population is in equilibrium, by equation (5) the catch will be a function of the fishing effort alone. It was argued earlier that the input, fishing effort, is not a measure that allows for an economic interpretation of the production function; for this reason, it is disaggregated into variable and fixed inputs that are economically measurable. Hence, the fishing effort per period of time, E_t, is a function of the vector of the variable and fixed inputs, U:

$$E_t = g(U) \tag{9}$$

Therefore, the catch per period of time is also a function of the same vector, U:

$$Q_t = h(U), \tag{10}$$

where the vector $U = (u_1, \ldots, u_r, u_{r+1}, \ldots, u_s)$ with $u_1, \ldots, u_r$ the variable inputs and $u_{r+1}, \ldots, u_s$ the fixed inputs.

It is assumed that the function in Equation (10) has the standard regularity conditions; i.e., h(U) is a finite, non-negative, real-valued, continuous, smooth, monotonic, concave, twice differentiable and bounded function (Lau, 1978).

The function is smooth if it is continous and differentiable on the domain over the non-negative orthant. Concavity and twice differentiability together imply that for each vector of fixed inputs, both the Hessian and bordered Hessian determinants are negative definite. That is, if the principal minor determinants of order k have sign (-1) for k = 1, ..., n in the Hessian and for k = 2, ..., n in the bordered Hessian matrix (Varian,

p. 310).

The above assumptions imply that the function estimated from the given set of data is unbroken (the continuity assumption). This is not an unrealistic assumption since there is not much variation in technology and input quality in the data used for this study. The above assumptions also imply that responses from the combinations of inputs are within the domain of the function and can only take real number values greater than or equal to zero (inputs and output are not negative). Further, it is assumed that the function is increasing with increasing input quantities (monotonicity assumption); that is larger catches are expected as the input vector increases. The concavity assumption implies that the function has an absolute maximum if it is strictly concave; this assumption is compatible with that of the general shape of the biological production function of a fishery. Finally, there are attainable solutions for all variable input combinations for each fixed input vector (the boundary assumption).

Because the production process of the reef fishery is of joint production due to technical interdependence of the fishing gear, different species have the probability of being caught when the gear is set on a fishing ground. Even if this were not the case, the existing information is aggregated over the fishing season and does not allow differentiation for allocating inputs to a specific species by periods throughout the season. Therefore, and assuming constant prices, the output flow will be a weighted index of gross revenue per fishing season, i.e., the physical output (catch) is converted into revenue (catch x price). The production function in equation (10) is then transformed into a gross revenue function whose response is explained by the variable and fixed inputs in the vector $U = (u_1, \ldots, u_r, u_{r+1}, \ldots, u_s)$.

The main criterion in selecting the explanatory variables is that the input have a measurable economic value and that factor substitution be allowed, so that the least cost input combination can be sought by individual firms. These criteria must also be compatible with the data available. Having this in mind, the inputs preliminarily identified for consideration in the model are:

(a) labor: the size of the crew changes not only with a boat's characteristics or its level of automation, but also in each boat throughout the fishing season. This change in the amount of labor may result from a combination of an increase in production from fishing during the season and an excess labor supply from other similar activities.

(b) materials: two main variable factors are considered here, fuel and amount of fishing gear. Fuel, apart from being a relevant cost can also represent an index for the geographic distribution of the effort of individual vessels. The fishing gear in this case is considered as material instead of capital because it is consumed quickly; it is expressed in terms of lines or reels per boat and can be considered as an index of the fishing effort on a particular fishing ground. Consequently, its amount may vary with the fishing ground; also, it tends to vary with crew size and in the same direction, so it may cause multicollinearity when both are included in the model.

(c) time: is explicitly included in the model as the number of fishing trips in the season. It accounts for the number of production cycles within the fishing season and is hypothesized to be a relevant explanatory variable because the probability of a larger catch increases in proportion to the number of trips.

(d) capital index: accounts for the fixed factor: As a substitute for capital value the tonnage of the boat will be postulated as fixed input. It gives a proxy for capacity and is generally related to other dimensions of the boat.

Therefore, the gross revenue function is:

$$Y = f(u_1, u_2, u_3, u_4, u_5) \tag{11}$$

where:

Y = Gross revenue per boat per fishing season

u_1 = Number of man-trips per season

u_2 = Gallons of fuel consumed in the season

u_3 = Number of gear-trips in the season

u_4 = Number of fishing trips per season

u_5 = Tonnage of the boat.

One factor not included in the model is entrepreneurship; the level of catch can be influenced greatly by the experience and skill of the captain and the crew. Years of experience or level of education are variables that have been frequently used as a measure of skill in this kind of analysis. Available data does not include indexes that allow measurement of the entrepreneurship factor effect.

Econometric Model

The translog functional form is here proposed to explain relationships between revenues and physical variable and fixed inputs. The function is quadratic in the logarithms of the variables. It does not imply homogeneity as part of the maintained hypothesis and also allows for a greater variety of substitution (Christensen et al., 1973). The Cobb-Douglas (CD) is a special case of the translog. The question of unitary elasticity of factor substitution, one of the properties of the CD function, might be an unrealistic assumption in a fishery;

inputs seem to have limited substitution and in some cases pairs of inputs tend to move in the same direction.

The translog function is also flexible because it can be expressed as an equation that gives a second-order Taylor's approximation; the relevance of this is that for a relative extremum of the function a general test for a relative maximum or minimum can be developed (Chiang, pp. 263).

The general representation of the translog function in this case is:

$$\ln Y = \beta_0 + \sum_{i=1}^{p} \beta_i \ln u_i + 1/2 \sum_{i=1}^{p} \sum_{j=1}^{q} \beta_{ij} \ln u_i \ln u_j + \varepsilon \quad (12)$$

with the following properties:

i. It meets symmetry conditions stated by Young's theorem; i.e, the second order cross partial derivatives are identical with each other as long as the two cross partial derivatives are both continuous. That is:

$$\frac{\partial^2 \ln Y}{\partial \ln u_i \, \partial \ln u_j} = \frac{\partial^2 \ln Y}{\partial \ln u_j \, \partial \ln u_i}$$

therefore $\beta_{ij} = \beta_{ji}$

ii. It has the property of constant returns to scale if and only if:

a) property i holds

b) $\sum_{i=1}^{p} \beta_i = 1$ and $\sum_{j=1}^{q} \beta_{ij} = 0$ for all i's and j's

This property implies linear homogeneity in factor quantities. If $\beta_{ij} = 0$ for all i's and j's, then the translog becomes the Cobb-Douglas functional form.

The first partial derivatives of the function in equation (12) represent the elasticity of total revenue defined as the proportionate change in the revenue with respect to the proportionate change in the i^{th} input:

$$\frac{\partial \ln Y}{\partial \ln u_i} = \frac{\partial Y}{\partial u_i} \frac{u_i}{Y} \equiv \eta_i \qquad (13)$$

and

$$\eta_i = \beta_i + \sum_{j=1}^{q} \beta_{ij} \ln_j \qquad (14)$$

For the Cobb-Douglas, in equation (6), the elasticity of revenue with respect to the i^{th} input will become the value of its corresponding coefficient.

Under the assumption that all fishing firms in the fishery are profit maximizers, factors of production must be paid the value of their marginal productivity; so that at constant prices

$$\frac{\partial Y}{\partial u_i} = r_i \qquad (15)$$

where r_i is the price paid for the i^{th} input. Therefore, the elasticity of the gross revenue, η_i, is identically equal to the factor share of the i^{th} input; that is

$$\eta_i \equiv s_i = \frac{r_i\ u_i}{Y} \tag{16}$$

The factor share represents the total expenditure in the i^{th} factor with respect to the total or gross revenue; the sum of all factor shares must add to unity.

Similar conditions apply to the Cobb-Douglas form where input coefficients will represent the factor share of each of the inputs. If this function exhibits constant return to scale, factor shares will add to unity.

The hypothesis of profit maximization for small scale fishing firms can be easily criticized. For example, fishermen act in an environment where lack of information is a part of their decisions. On the other hand, fishermen may pursue different goals other than profit maximization. Poggie and Gersuny (1974) suggested that in some fisheries fishing is a way of life rather than an occupation, where non-material incentives prevail. Objectives such as obtaining the largest catch or pursuing a particular type of fishing strategy which may be economically inefficient are found among fishermen. Also, some cultural factors can prevail over profit optimizing behavior. Pollnac (1982) described examples where improved technology has not been substituted for labor and where new technology has had to be abandoned because of the negative impact in the fishing community. There may be other situations where fishermen do not optimize economic behavior. Nevertheless, the hypothesis of profit maximization is a good reference point for measuring the performance of the fisherman's economic activity and in this sense it is used here.

Estimation Procedure of the Econometric Model

The hypothesis of profit maximization allows estimation of five factor share equations of the form in Equation (14) where the i^{th} share is defined as follows:

s_1: labor share, explicitly recorded during the survey.

s_2: fuel share; ratio of total expenditure in fuel to total revenue.

s_3: gear share; ratio of total expenditure on gear repair and replacement plus bait expenses to the total revenue.

s_4: operating expenses share; ratio of other variable costs, such as hull and engine repairs and similar types of costs to the total revenue.

s_5: capital services share; it is the difference between one and the summation of the remaining shares. It includes fixed expenditures and payment to capital (profit) and to fish resource (resource rent).

Each of the five factor share equations can be separately estimated using the ordinary least squares technique (OLS). However, if some degree of correlation exists among residuals of the equations, the OLS will not produce an efficient estimation. In this case, the system is known as the seemingly unrelated regression equations, whose coefficients are jointly estimated by the Zellner generalized least squares (GLS) procedure (see Kmenta, pp. 635-643).

The Zellner GLS procedure first estimates the regression coefficients separately for each equation using OLS. In matrix notation these are estimated as:

$$\hat{\beta}_m' = (X_m' X_m)^{-1} (X_m' Y_m) \quad \text{for all } m = 1, 2, \ldots, M$$

The next step is to perform the joint estimation of the coefficient considering all M equations simultaneously, that is:

$$\tilde{\beta} = (X' \Omega^{-1} X)^{-1} (X' \Omega^{-1} y)$$

where

$\tilde{\beta}$: is the ($\sum_{m=1}^{M}$ K 1) matrix with K being the number of coeffients in the m^{th} equation;

X: is the (M T · $\sum_{m=1}^{M}$ K) matrix with T being the number of observations in the m^{th} equation;

y: is the (M T · 1) matrix; and

Ω: is the (M · M) variance-covariance matrix of the residuals obtained from the OLS estimation. More explicitly,

$$\Omega = \begin{bmatrix} \sigma_{11}\ I_T & & \text{(symmetric)} & \\ \sigma_{21}\ I_T & \sigma_{22}\ I_T & & \\ \vdots & \vdots & & \\ \sigma_{m1}\ I_T & \sigma_{m2}\ IT & \cdots\cdots\cdots & \sigma_{mn}\ I_T \end{bmatrix}$$

where I_T is the identity matrix (T x T) and σ_{mn} is the covariance of the residuals of the m^{th} and n^{th} equations; σ_{mn} is assumed to be constant for all observations where m ≠ n, but $\sigma_{ij} = 0$ for all observations for i ≠ j when m = n and the covariance is σ_{mm}.

Considering the restrictions imposed on the coefficients of the translog functions in order to achieve symmetry and constant return to scale conditions, the joint GLS procedure is applied to M - 1 equations since one of them becomes redundant. For a well behaved function all elasticities of gross revenues are expected to be positive.

In summary, in estimating economic production relationships in small scale fisheries, this thesis proposes a model that allows estimation of revenue shares of factor of production. The model is based on the proposition that the gross revenue or total value product is a function of labor, amount of fishing gear, fuel, number of fishing trips, and tonnage of the boat. The proposed functional form is the transcendental logarithmic function. Assuming that fishermen are profit maximizers, the first partial derivative of the gross revenue function is equal to the revenue share of each input, which is also identically equal to the elasticity of the gross revenue. Imposing symmetry and honogeneity restrictions on the translog function, the coefficients for M-1 factor share equations are to be estimated using the Zellner generalized least squares procedure for seemingly unrelated regressions.

CHAPTER V

RESULTS OF MODEL ESTIMATION

Test of Functional Form

In order to test the functional form, regression coefficients for both the translog and the Cobb-Douglas forms were first estimated by the OLS technique. Results are reported in Table 2.

Subsequently the Breusch-Pagan test for homoskedasticity (Kmenta, pp. 294-98) was performed on both estimated equations. The RSS/2 statistics were 16.29 and 4.81 for the translog and CD functions respectively; these results imply that the tests on both functions are insignificant at .05 level of significance for a chi-squared distribution with 20 and 5 degrees of freedom, respectively. It is then concluded that neither of the two functions are heteroskedastic. An explanation of the Breusch-Pagan test is found in Appendix B.

The generalized F-test (see Appendix B for explanation) for testing the functional form was performed. The null hypothesis that all B_{ij}'s are equal to zero was stated. The estimated F-statistic was 1.934, which is significant at the .05 level for an F distribution with 15 and 65 degrees of freedom. This implies that the null hypothesis is rejected, and consequently, the translog functional form is adopted; although the contri-

Table 2. Estimated Parameters of the Translog and Cobb-Douglas Functions Using OLS Method.

	Translog		Cobb-Douglas	
Parameters	Estimate	t-Statistics	Estimate	t-Statistics
Constant	6.947	1.411	4.471	6.398***
B_1	1.565	.510	.126	.669
B_2	-2.631	-1.515	.578	4.868***
B_3	-1.971	- .621	- .175	-1.009
B_4	5.054	2.602***	.346	2.593***
B_5	3.619	1.813*	.178	1.279
B_{11}	.338	.507		
B_{12}	.035	.062		
B_{13}	.445	- .671		
B_{14}	- .772	-1.194		
B_{15}	.317	.491		
B_{22}	.972	2.131**		
B_{23}	.240	.546		
B_{24}	- .688	-1.555		
B_{25}	-1.206	-3.047***		
B_{33}	.517	.647		
B_{34}	- .244	- .394		
B_{35}	.057	.081		
B_{44}	- .350	- .858		
B_{45}	1.130	2.729***		
B_{55}	1.080	2.239**		
Statistics:				
R^2	.72		.59	
D-W	1.84		1.83	
Level of Significance	.76		.84	
n	86		86	

* = significant at .10 level
** = significant at .05 level
*** = significant at .01 level

bution of the quadratic and interaction terms for explaining revenue variation is only about 13 percent of the total. The first order term explains about 59 percent of the total variation and the rest is absorbed by the error term.

The translog model shows signs of multicollinearity. There is a high level of explanation by the regressors accompanied by low and insignificant values for most of the regression coefficients.

To determine the presence of multicollinearity in the translog gross revenue function, the method of principal components analysis (see Koutsoysiannis, pp. 424-36) was used. The method determines (a) which varibles in the regression equation are correlated, and (b) the loading contribution of each variable to the principal components. It was found that the first principal component represents 62 percent of the total variation of the fitted translog revenue function. Eight independent variables were associated with the contribution of the first principal component, each contributing with the same loading, approximately 94 percent of the 62 percent variation. Similarly, the second principal component represented 23 percent of the total variation of the revenue function. Three independent variables were associated with the contribution of the second principal component, each contributing with the same loading, approximately 92 percent of the 23 percent variation. These results imply that variables with similar high loadings demonstrate the presence of multicollinearity in the revenue function. Multicollinearity was expected primarily because variables in the second order term are constructed from the ones in the first order term of the model. Also, because of the small data set used in the model estimation the degrees of freedom were small. Nevertheless, it can be noticed that some of the interaction coefficients are significant at the .05 level of significance; e.g, number of trips and boat tonnage and boat tonnage by itself interact positively, whereas fuel consumption and tonnage unexpectedly interact negatively.

Factor Share Equations

The estimated coefficients for the unrestricted factor share (elasticity of revenue) equations of the form:

$$s_{it} = B_i + \sum_{j=1}^{5} B_{ij} \ln u_{jt} + e_{it}, \qquad (17)$$

for all i = 1,....,5, are reported in Table 3. As explanatory variables and the data set used for estimating the share equations are the same, there is no difference in applying the OLS or the unrestricted joint GLS method; in this case the equations are not related (Kmenta, p. 639).

Estimating these equations instead of the full translog form reduces the probability of multicollinearity. Their joint estimation allows for the sym-

Table 3. Estimated Parameters of Four Factor Share Equations Using Unrestricted Joint GLS Method.

Share	Labor (U_1)	Fuel (U_2)	Gear (U_3)	Operating Expenditures (U_4)
B_i	.238	- .163	.620	1.282
	(1.397)	(-1.203)	(4.709)***	(5.251)***
B_{1j}	.129	- .013	.036	.055
	(2.818)***	(- .368)	(1.013)	(.837)
B_{2j}	- .008	.056	- .037	- .105
	(- .269)	(2.445)***	(-1.659)*	(-2.537)***
B_{3j}	- .003	.025	- .026	- .009
	(- .079)	(.740)	(- .804)	(- .148)
B_{4j}	- .124	- .057	- .044	- .136
	(-2.201)**	(-1.262)	(-1.006)	(-1.688)*
B_{5j}	.047	- .021	- .214	- .004
	(1.394)	(- .770)	(- .815)	(- .089)
Statistics				
R^2	.21	.09	.17	.27
$\bar{R}^2$	.16	.04	.12	.23
D-W	1.48	1.68	1.67	1.74
Significance Level	.40	.98	.10	.99
n	86	86	86	86

t-statistics in parentheses.

* = significant at .10 level.
** = significant at .05 level.
*** = significant at .01 level.

metric and constant return to scale conditions of the translog. By imposing these two restrictions, there is a loss in the coefficients of determination, between .02 and .18 with respect to the unrestricted equations. Table 4 shows the estimated regression coefficients for the restricted share equations.

For testing the simultaneous restrictions of symmetry and homogeneity, the test for a set of linear restrictions (see Appendix B) was performed. This test is imposed simultaneously on a set of different equations (see Judge et al., pp. 189-204, and 315-328). The null hypothesis in this test is that the matrix of restrictions times the vector of number of coefficients is equal to the vector of restrictions, which takes the value of one for each symmetry and zero for each homogeneity restriction. The statistic is a chi-squared distribution with degrees of freedom equal to the total number of restrictions in all equations. In the present situation, the total number of restrictions on the four estimated share equations was 10, dstributed in (a) six symmetry restrictions, which correspond to six different pairs of equal coefficients; and (b) four homogeneity restrictions, which correspond to the four equations, each of whose coefficients add up to zero. The resulting sample value of the chi-squared distribution with 10 degrees of freedom was 40.42, which is significant at the .05 level. Therefore, the null hypothesis that the restricted regression coefficients of the share equations

Table 4. Estimated Parameters of Four Factor Share Equations Using Restricted Joint GLS Method.

Share (S_i)	Labor (U_1)	Fuel (U_2)	Gear (U_3)	Operating Expenditures (U_4)
B_i	.432 (3.987)***	- .316 (-3.353)***	.210 (2.570)***	.440 (3.992)***
B_{1j}	.103 (2.457)***		(symmetric)	
B_{2j}	- .012 (- .529)	.086 (5.107)***		
B_{3j}	- .011 (- .502)	- .005 (- .391)	- .030 (-1.299)	
B_{4j}	- .109 (-3.432)***	- .043 (-2.398)***	.023 (.967)	.027 (.705)
B_{5j}	.029 (1.459)	- .025 (-1.534)	.023 (1.504)	.102 (3.861)***
Statistics				
R^2	.19	.06	.03	.09
$\bar{R}^2$	.14	.00	.00	.03
D-W	1.54	1.73	1.66	1.74
Significance Level	.30	.99	.91	.94
n	86	86	86	86

t-statistics in parentheses.

* = significant at .10 level.
** = significant at .05 level.
*** = significant at .01 level.

are the true statistics is rejected. Consequently, the simultaneously required properties of symmetry and constant returns to scale for the translog are not achieved in the present case (explanations of the test are found in Appendix B). However, data inconsistencies may have affected the results.

For example, the correlation matrix of factor shares and the log transformation of physical input quantities in Table 5 show in general a low linear association between the factor shares and its corresponding factor. Even more, when correlation between the two tend to be higher, the sign is opposite to what it should be, as in the case of gear and operating expenses shares. Similarly, when there is a high correlation between a pair of inputs it is expected that both show some positive level of linear association with one of the corresponding factor share. This is not the case with the correlation between the labor share and the log of gear and trips. Although both are correlated with labor, they are negatively correlated with the labor share. Similar situations occur between the operating expenses share and the log of fuel consumption, where this is correlated with the number of fishing trips. This would in part suggest that the lack of explanation of the regressors in the variation of the factor shares are due to data inconsistency.

Some of the features of the data which may explain its inconsistency are: (a) the labor share reported may

Table 5. Correlation Matrix Between Variables in the Factor Shares Model.

	s_1	s_2	s_3	s_4	$\ln u_1$	$\ln u_2$	$\ln u_3$	$\ln u_4$	$\ln u_5$
s_1	1.00								
s_2	.14	1.00							
s_3	.06	.45	1.00						
s_4	.03	.30	.54	1.00					
$\ln u_1$	.12	.02	-.28	-.40	1.00				
$\ln u_2$	.19	.23	-.35	-.43	.63	1.00			
$\ln u_3$	-.09	-.01	-.31	-.38	.73	.39	1.00		
$\ln u_4$	-.16	-.07	-.29	-.42	.78	.38	.85	1.00	
$\ln u_5$	.35	.15	-.17	-.11	.14	.54	-.06	-.20	1.00

not be accurate since there is evidence that not all crew members were included in the reported share for several of the boats surveyed; (b) each fishing trip was assumed to have the same duration for all fishing boats (a more accurate assumption is that trip duration varies from boat to boat according to their fishing strategies); and (c) the estimation of the amount of labor and fishing gear was assumed to be constant per fishing trip, which is inaccurate. Most interviewees reported not only average crew size, but also its minimum and maximum. On the other hand, if the duration of the fishing trips is not the same for all boats, then the number of times that the fishing gear is set in the water may vary, other things being constant. Furthermore, the total physical quantities of the two inputs were estimated by multiplying their average quantity reported by each boat times the number of fishing trips in the season. This explains the high correlation between the labor and gear inputs with the time variable, which would have been lower otherwise.

An additional problem is whether or not the sample is representative of the current population. For example, according to the interviewers (Nero and Associates, Inc., 1981), there is evidence that the survey may have been biased toward the smaller boats.

Results for the Cobb-Douglas Formulation

The estimated parameters for the linearized CD function:

$$\ln Y_t = B_0 + \sum_{i=1}^{5} B_i \ln u_{it} + e_t \tag{18}$$

are reported in Table 2. About .59 percent of the variation on the log of total revenue is explained by the variables in the model.

As in the factor shares model, the regression coefficients in the CD function seemed very sensitive to variable substitution or deletion. Further, not all coefficients showed the expected positive sign. Again, lack of data consistency might be a major problem. The correlation matrix in Table 6 shows acceptable levels of linear association between the dependent and each of the independent variables.

Economic Interpretation of Results

Assuming that the estimated coefficients of the share equations represent true values, the efficiency of production can be observed by comparing their fitted value, which will vary with the size of the firm (the fishing boat) and its production plan, against the observed factor share value at the current market price of the i^th input; or, from Equations (16) and (17). The efficiency of production is then expressed as:

$$(B_i + \sum_{j=1}^{5} B_{ij} \ln u_j) \frac{Y}{u_i} = r_i \tag{19}$$

Table 6. Correlation Matrix Between Variables in the Cobb-Douglas Model.

	ln Y	ln u_1	ln u_2	ln u_3	ln u_4	ln u_5
ln Y	1.0					
ln u_1	.59	1.0				
ln u_2	.74	.63	1.0			
ln u_3	.39	.73	.39	1.0		
ln u_4	.44	.74	.38	.85	1.0	
ln u_5	.39	.14	.55	-.06	-.20	1.0

If the r_ith value for the ith input is greater than the market value, then input usage should be expanded; if it is smaller, then market value usage should be reduced. Two comments may be made in this respect: first, the market value of the inputs are not directly observable, except the fuel price, although some proxy can be used. For example, the labor market price can be based on the opportunity cost of similar activity in an alternative fishery. Market prices for gear and operating expenses can be based upon the current prices for repair and maintenance, their major components. Prices for capital services can be evaluated by the oportunity cost of similar investment.

Second, as inputs interact among themselves equating Equation (19) for production efficiency of one input will affect the share of the others. This implies that the system of M efficiency equations should be solved simultaneously. If the equations in this system are unconstrained, to obtain the level of inputs for efficient production of a firm, it is enough to solve such a system expressed in matrix notation as:

$$B\ X = R \qquad (20)$$

where:

B is the (5x5) matrix of $B_{ij}\ \frac{Y}{u_i}$

X is the (5x1) matrix of $\ln u_j$, and

R is the (5x1) matrix of $[r - B_i \frac{Y}{u_i}]$

This matrix should be non-singular for a unique solution.

If the firm is only interested in changes in revenue, the fitted values of the share equations are taken as the elasticity of revenue instead of the factor share. Obviously, the elasticity value will vary for each firm. Now supposing that the firm decides to increase the amount of the ith input by one percent, then its own elasticity will change by the value of its regression coefficient since

$$\frac{\partial^2 \ln Y}{\partial(\ln u)^2} = B_{ii}$$

Furthermore, as other elasticities are also functions of the same input the effects of their changes, the cross partial elasticty of the revenue, are measured by the value of the interaction coefficient since

$$\frac{\partial^2 \ln Y}{\partial \ln u_i \; \partial \ln u_j} = B_{ij}$$

From the property of constant returns to scale, CRS, of the translog it is recalled that the summation of elasticities must add to one. Therefore, all five elasticities can be estimated each time the firm decides to make changes in the input quantity.

Changes in elasticities of revenue due to own inputs are expected to have positive signs; however, from Table 4 it is seen that this is not the case for the gear input, which is -.03, or for boat capacity (tonnage of the boat), which is -.13 as estimated from the CRS property.

Nevertheless, regarding changes in elasticities, some empirical considerations can be drawn from these results. For example, varying number of trips by one percent, with other inputs held constant will produce the biggest change in the elasticty of revenue (or in the factor share) with respect to the boat capacity. The change is approximately .10 percent which is the value for the interaction coefficient of these two inputs. So, a change in the elasticity of revenue with respect to the boat capacity due to a change in number of trips alone will produce the biggest change in total revenue when the boat capacity changes. If all variable inputs were simultaneously changed by one percent, there would be approximately a .13 percent increase in the revenue elasticity of boat capacity. But this also can be interpreted as a .13 percent increase in the capital service share which supposedly contains elements of profit in its composition. By changing labor, gear and trips factors, holding fuel constant, the increment in profit would be as much as .15 percent per one percent change in the three inputs simultaneously, if capital rent were the only element in the capital service share.

The preceding example should be taken as an illustrative application of the results that can be obtained by applying the methodology used here. In general, this methodology provides simultaneous information for varied objectives of decision making and policy analysis.

In the CD model, unlike the translog function, output elasticities are constant and are represented by the value of the regression coefficients. The elasticities are independent of the other inputs. The greatest proportional increase in revenues is given by fuel consumption which would imply that further fishing grounds give better catch yield, other factors held constant. The elasticity of boat capacity is not only small, but insignificant, which would suggest that changes in it do not affect the revenue; this is an arguable result that also differs from the one obtained in the translog model. Revenue elasticities of labor and gear were also insignificant. Therefore, according to the CD formulation, only fuel and number of trips produce changes in gross revenues.

Production efficiency is calculated by equating the regression coefficient of the ith input to the corresponding share evaluated at its market price. Here, as in the output elasticities, production efficiency is evaluated separately and independent among inputs because the CD formulation does not allow for input interactions.

The sum of the regression coefficients of the inputs is 1.05 which is very close to one, suggesting that the CD function would also exhibit constant returns to scale. For testing this hypothesis, the F-test in Appendix B was used. The estimated F statistic was .40, that is less than 3.97 the value of F at .05 level of significance with one and 80 degrees of freedom. The null hypothesis is accepted: constant returns to scale may prevail in the fishery according to the CD formulation. The result would also support the CRS restriction imposed on the translog function.

When a model exhibits CRS, the regression coefficients of the CD function also represent the factor shares of the inputs and their sum must add to one. This would suggest that at least all inputs subject to economic evaluation are present in the CD model; but also that, given the low value for the capital service share, profit in the fishery is low for the period analyzed.

By comparing the economic implications of both the translog and the CD functions, it is concluded that the translog can give a more realistic representation of production relationships than the CD function. That is (1) it can show marginal productivity less, equal to, and greater than zero. This is a closer representation of the biological production function; (b) its elasticity of substitution is non-constant. In small scale fisheries proportionate variation in input ratio may be different than the proportionate variation of price ratio; and (c) elasticities and factor shares are functions of the inputs -- hence their values are non-constant. This suggests that changing inputs in bundles rather than individually is more efficient.

Nevertheless, the share equation model based on a translog revenue function showed a poor response. Further properties of symmetry and constant returns to scale were rejected. In part this is attributable to the data set used. Therefore, a more conclusive opinion about the factor shares model for the available information of the Florida reef or any other in small scale fishery can be obtained by using a larger and more accurate set of data.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The objective of this research was to find a better method of estimating economic production relationships in small scale fisheries. It has been indicated that lack of understanding of production relationships in small scale fisheries limits the design for successful development and management programs. Simultaneously, the literature available on the estimation of production relationships in small scale fisheries is not abundant. Consequently, there is a lack of methodological experience. Also, available data for estimating small scale fisheries production relationships is notoriously incomplete and inacurate. Therefore, a contribution can be made to improved fishery development and management and to improved fishing business management if an improved method of estimating production relationships can be demonstrated.

The proposed method makes use of a transcendental logarithmic function to postulate that gross revenue is a function of the physical input quantities. The translog was selected because of its flexibility, non-constant elasticity of substitution and because of the interaction between inputs. Further, by assuming that fishermen are profit maximizers and given the property of constant returns to scale and symmetry that is imposed on the translog function, the method estimates five factor share equations instead of the primal function. The factor shares are identically equal to the marginal values of the original function. The factor shares are also equivalent to the elasticities of revenue.

The model construction and estimation was based on a set of cross-sectional data from a cost and earning survey of the Florida reef fishery. For estimating the share equations, the joint generalized least squares procedure for seemingly unrelated equations was applied. A total of 86 observations were used. Estimation results were not very encouraging because the hypothesis for linear restrictions imposed on the coefficients of the factor share equations was rejected. However, further examination of the data and their corresponding correlation matrix suggested inconsistencies in the data which may partially explain the poor model response. This was expected because cross-sectional data collected from small scale fisheries through questionnaires are typically not very accurate.

In terms of policy implications for fisheries development and management, any type of model on production relationships can help in understanding these relationships, assuming it has a good fit and it is well behaved. Two factors make the proposed model especially attractive: (1) unlike other models, factor shares and elasticities are functions of inputs; and (2) it allows varying the inputs in bundles instead of individually, which can be more efficient depending on the decision objectives. For example, according to the results obtained, the highest increase in elasticity of revenue is obtained by increasing labor and boat size simultaneously. This also means an increase in the labor share but a decrease in the capital service share. Hence, it shows what may happen when employment is increased. Similarly, other bundles of input variation can be considered for different objectives.

The result of the primal translog function estimation showed that the independent variables explained 72 percent of the variation in the dependent variable in comparison to the 59 percent showed by the Cobb-Douglas formulation. However, the model was characterized by multicollinearity and sensitivity of parameters to variable substitution. This can be expected by recognizing the model is a second order approximation and the data set is not large enough to avoid these problems. Estimating the primal function directly is an attractive alternative, especially when information on input expenditure is not available. The first partial derivative of the model becomes the output elasticity of the ith input. If revenue is used as the dependent variable it becomes the factor share of the $i^{\underline{th}}$ input. Further, if all expenditures, including capital service cost, are represented in the model by the explanatory variables, the sum of factor shares must add to one. Because of this summation restriction, the method of choice in this case should be to estimate the share equations instead of the primal function directly.

The Cobb-Douglas functional form showed good response and behavior when the same variables were used. Multicollinearity was also present. However, not all signs of the regression coefficients were positive as expected. Again, the problem is mostly associated with data inconsistency. This made the Cobb-Douglas an interesting means of comparison with the translog function. In this case the Cobb-Douglas function exhibited constant returns to scale. Further, because of its simplicity the Cobb-Douglas formulation is also a good reference for comparing other behavior of the models.

Model estimation could be enhanced if more complete information on the variables were available. This would help reduce the dependency between certain variables. In this particular case variables such as labor and fishing gear depended upon the time variable. The model also requires more accurate data on capital values and depreciation to measure the effect of varying input on the return to capital and to the fishery resource.

The method presented here can give a more realistic representation of economic production relationships in small scale fisheries than others currently available. It is a start at providing better information for policy decision and analysis in small scale fisheries. However, as model response and behavior was not satisfactory, it should be tested with a more accurate and larger set of data.

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APPENDICIES

APPENDIX A

Questionnaire

QUESTIONNAIRE

1. Card Number __
   1

2. Interview Number __ __
   2 3

3. Interviewer Number __ __ __
   4 5 6

4. Date of Interview __ __/__ __/ __ __
   7 8 9 10 11 12

5. County/State______________________ __ __
   13 14

Hello, my name is ____________, and I'm conducting a survey today for the National Marine Fisheries Service. The purpose of the study is to collect information from commercial fishermen, such as yourself, to assist in the management of the fisheries. The information you give us will be strictly confidential and your name will not appear on the questionnaire. If you would like to see it, I have a copy of the Privacy Act of 1974, which explains how any information you give us will be used. Basically, all the information we collect will be gathered together so the identity of any individual is not part of this study. We want to talk to you about reef fishing.

I hope you have the time to participate in this interview; it will take between 25 and 30 minutes.

_____ Unable to Proceed Reason: ______________________________

____

A. CAPITAL INVESTMENT

A1. Vessel:

6. Documentation Number: __ __ __ __ __ __
   15 16 17 18 19 20

7. Length: __ __ ft.
   21 22

8. Tonnage: __ __
   23 24

9. Fabrication (wood, steel) __________ __
   25

10. Year Originally Built __ __
    26 27

11. Purchased or Built By Fisherman ______________________ __
    28

12. Year Purchased: __ __
    29 30

13. Initial Cost $__, __ __ __,000
    31 32 33 34

14. Year Boat Rebuilt: __ __
    35 36

15. Cost to Rebuild $__ __ __,000
    37 38 39

16. Present Sale Price With Gear: $__, __ __ __,000
40 41 42 43

17. Expected Life: __ __ years (from date of purchase)
44 45

18. Vessel Owner-Operated? Yes No __
46

A2. Engine:

19. Type (diesel or gasoline) ______________ __
47

20. Make ____________________ __ __
48 49

21. Size __ __ __ hp
50 51 52

22. Year Engine Rebuilt or Replaced: __ __
53 54

23. Expected Life: __ __ years
55 56

A3. Equipment: Does this vessel have:

24. Radar? Yes No __
57

25. How many? ____________________
58

26. Loran? Yes No __
59

27. How many? ____________________
60

28. VHF? Yes No __
61

29. How many? ____________________
62

30. Paper Machine/Fish Recorder?
Yes No __
63

31. How many? ____________________
64

32. Refrigeration? Yes No __
65

33. How many? ____________________
66

34. CB Communication? Yes No __
67

35. How many? ____________________
68

36. Auto-Pilot? Yes No __
69

37. How many? ____________________
70

B. EFFORT

B1. Home Port:

38. City: ________________ __ __
71 72

39. County/State: _____________ __ __
73 74

B2. Trips:

40. Number: __ __ __ per year for reef fishing.
75 76 77

(Card Number: __ 1 Interviewer No. __ __ 2 3 Interview No. __ __ __ 4 5 6

Vessel Documentation No. __ __ __ __ __ __
7 8 9 10 11 12

41. What percentage of your time is spent reef fishing? __ __ __
13 14 15

42. Average time gear is in water (in hours): __ __
16 17

Amount of Gear Per Trip:

43. Land Lines: __ __
18 19

44. Traps: __ __
20 21

45. Other: __ __
22 23

B3. Location:

Think of the place you reef fish most frequently:

46. How many miles is it from your home port? __, __ __ __
24 25 26 27

47. What percentage of your time reef fishing do you spend there? __ __ __%
28 29 30

48. How long do you leave your traps or lines at this location (in hours)? __ __
31 32

Think of the place you reef fish second most frequently:

49. How many miles is it from your home port? __, __ __ __
33 34 35 36

50. What percentage of your time reef fishing do you spend there? __ __%
37 38

51. How long do you leave your traps or lines at this location (in hours)? __ __
39 40

Think of the place you reef fish third most frequently:

52. How many miles is it from your home port? __, __ __ __
41 42 43 44

53. What percentage of your time reef fishing do you spend there? __ __%
45 46

54. How long do you leave your traps or lines at this location (in hours)? __ __
47 48

C. <u>CREW</u>

55. Minimum number of crew per trip: __ __
49 50

56. Maximum number of crew per trip: __ __
51 52

57. Average number of crew per trip: __ __
53 54

58. Is crew on shares? Yes No __
55

59. What is the share? __ __%
56 57

If now owner-operated, what is the share that goes to:

60. Captain: __ __%
58 59

61. Crew: __ __%
60 61

D. <u>COST: Annual Totals</u>

62. Insurance $ __ __, __ __ __
62 63 64 65 66

63. Licenses $ __ __, __ __ __
67 68 69 70 71

64. Vessel Taxes (property) $ __ __, __ __ __
72 73 74 75 76

(Card Number: __ 1   Interviewer No. __ __ 2 3   Interview No. __ __ __ 4 5 6

Vessel Documentation No. __ __ __ __ __ __ 7 8 9 10 11 12

65.	Depreciation		$ __ __, __ __ __ 13 14 15 16 17
66.	Interest - long-term debts		$ __ __, __ __ __ 18 19 20 21 22
67.	Interest - operating costs		$ __ __, __ __ __ 23 24 25 26 27
68.	Unloading and Packing fees		$ __, __ __ __ 28 29 30 31
69.	Association Dues		$ __ __ __ 32 33 34
70.	Fuel and Oil	__ __, __ __ __ Gallons 35 36 37 38 39	
71.	Fuel and Oil Cost		$ __ __, __ __ __ 40 41 42 43 44
72.	Groceries (cost to crew)		$ __, __ __ __ 45 46 47 48
73.	Bait		$ __, __ __ __ 49 50 51 52
74.	Ice	__ __ __, __ __ __ Pounds 53 54 55 56 57 58	
75.	Ice - Cost		$ __ __, __ __ __ 59 60 61 62 63
76.	Gear Replacement		$ __ __, __ __ __ 64 65 66 67 68
77.	Gear Depreciation		$ __ __, __ __ __ 69 70 71 72 73

(Card Number: __ Interviewer No. __ __ Interview No. __ __ __
1 2 3 4 5 6

Vessel Documentation No. __ __ __ __ __ __
7 8 9 10 11 12

Repairs and Maintenance

78. Hull $__ __ __, __ __ __
13 14 15 16 17 18

79. Engine $ __ __, __ __ __
19 20 21 22 23

80. Repairs to Gear $ __ __, __ __ __
24 25 26 27 28

81. Other Repairs and Maintenance____________ $ __ __, __ __ __
29 30 31 32 33

82. Total Cost of Vessel Maintenance $__ __ __, __ __ __
34 35 36 37 38 39

83. New Gear Purhcase (not replacements) $ __ __, __ __ __
40 41 42 43 44

84. Other Costs, Total ________________ $ __ __, __ __ __
45 46 47 48 49

85. **TOTAL COSTS** $ == == ==, == == ==
50 51 52 53 54 55

E. **CATCH/REVENUE: Annual Totals**

86. Species #1: ____________ __ __ 87. Pounds Landed: __ __ __, __ __ __
56 57 58 59 60 61 62 63

88. Revenue: $__ __, __ __ __ 89. Location Sold: ________________ __ __
64 65 66 67 68 69 70

90. Other Location: ____________________________ __ __
71 72

(Card Number: __ Interviewer No. __ __ Interview No. __ __ __
1 2 3 4 5 6

Vessel Documentation No. __ __ __ __ __ __
7 8 9 10 11 12

91. Species #2: ____________ __ __
13 14

92. Pounds Landed: __ __ __, __ __ __
15 16 17 18 19 20

93. Revenue: $__ __, __ __ __
21 22 23 24 25

94. Location Sold: ________________ __ __
26 27

95. Other Location: ____________________________ __ __
28 29

96. Species #3: ____________ __ __
30 31

97. Pounds Landed: __ __ __, __ __ __
32 33 34 35 36 37

98. Revenue: $__ __, __ __ __
38 39 40 41 42

99. Location Sold: ________________ __ __
43 44

100. Other Location: ____________________________ __ __
45 46

101. Species #4: ____________ __ __
47 48

102. Pounds Landed: __ __ __, __ __ __
49 50 51 52 53 54

103. Revenue: $__ __, __ __ __
55 56 57 58 59

104. Location Sold: ________________ __ __
60 61

105. Other Location: ____________________________ __ __
62 63

106. Species #5: ____________ __ __
64 65

107. Pounds Landed: __ __ __, __ __ __
66 67 68 69 70 71

108. Revenue: $__ __, __ __ __
72 73 74 75 76

109. Location Sold: ________________ __ __
77 78

****

Thank you very much for your time and cooperation.

Someone from our area office will be making "spot check" telephone calls verifying that interviews were conducted. No additional data will be collected. Is it alright to verify that this interview took place?

Yes No ________/__________________________

Area Code Number of Interviewee

I hereby certify that this interview was actually taken and with the correct respondent and represents a true account of the interview.

_____________________________ _____________________

Interviewer's Signature Date

APPENDIX B

Test Statistics

APPENDIX B

TEST STATISTICS

The Breusch-Pagan Test for Homoskedasticity

Assuming that either of the two following models are to be tested for homoskedasticity, or any other linear model,

$$\ln Y_t = B_0 + \sum_{i=1}^{p} B_i \ln u_{it} + \tfrac{1}{2} \sum_{i=1}^{p}\sum_{j=1}^{q} b_{ij} \ln u_{it} \ln u_{jt} + e_t \qquad (1)$$

$$\ln Y_t = B_0 + \sum_{i=1}^{p} B_i \ln u_{it} + e_t \qquad (2)$$

the hypothesis are:

$$\text{Ho:} \quad \sigma_t^2 = \sigma_t^2 \qquad \text{for all } t = 1, 2, \ldots, T$$

$$\text{Ha:} \quad \sigma_t^2 = g(D_0 + D_1 Z_{1t} + \ldots. + D_i Z_{it})$$

where $g(\cdot)$ is a continuous function with continuous first derivatives and Z's are some known stochastic variables being typically the same as the explanatory variables of the regression equations (1) or (2) or some function of them.

The Breusch-Pagan statistics follows the chi-squared distribution with (k - 1) degrees of freedom,

$$SSR(bp)/2 \sim X_{k-1}^2$$

where SSR(bp) is the regression sum squared from the regression of $e_t^2/\hat{\sigma}^2$ on Z_{it}; that is

$$e_t^2/\hat{\sigma}^2 = D_0 + \sum_{i=1}^{p} D_i \ln u_{it} + \tfrac{1}{2} \sum_{i=1}^{p}\sum_{j=1}^{q} D_{ij} \ln u_{it} \ln u_{jt} + v_t$$

or

$$e_t^2/\hat{\sigma}^2 = D_0 + \sum_{i=1}^{p} D_i \ln u_{it} + w_t$$

where

e_t^2: the t^{th} squared residual in regression equations (1) or (2)

$\hat{\sigma}^2=\Sigma e_t^2/n$: sum of the squared residuals in equations (1) or (2) divided by the number of observations.

<u>Decision Rule</u>:

If RSS(bp)/2 $\leq X^2_{(\alpha,k-1)}$ the test is not significant and the null hypothesis is accepted; the regression equation presents homoskedasticity. Reject Ho otherwise.

Generalized F-Test

For the full model,

$$\ln Y = B_0 + \sum_{i=1}^{p} B_i \ln u_i + 1/2 \sum_{i=1}^{p} \sum_{j=1}^{q} B_{ij} \ln u_i \ \ln u_i + e$$

the following hypothesis are to be tested:

$Ho = B_{ij} = 0$ for all $i = 1, 2, \ldots, p$ and
$j = 1, 2, \ldots, q$

$Ha = B_{ij} \neq 0$, not all of the B_{ij}'s in Ho equal zero;

so that, the reduced model is

$$\ln Y = b_0 + \sum_{i=1}^{p} B_i \ln u_i + v$$

The test is based on the F statistics:

$$F^* = \frac{SSE(r) - SSE(f)}{df(r) - df(f)} \div \frac{SSE(f)}{df(f)}$$

where F* has an F distribution for α level of significance with (k(f) - k(r)) and (n - k(f)) degree of freedom and SSE(r) and SSE(f) are the sum of the squared errors for the reduced and full model, respectively. df(r) and df(f) are the degree of freedom of the reduced and full mode, respectively. n is the number of observations. k(r) and k(f) are the number of parameters in the reduced and the full model respectively.

Decision Rule

If $F^* > F_{[\alpha,\ k(f)-k(r);\ n-k(f)\}}$ the test is significant and the null hypothesis is rejected; the B_{ij}'s should not be dropped from the model. Accept Ho otherwise.

Test for Restriction Imposes on the Relationship Between Parameters of a Function

The test is an F-statistics estimated on the sum of squared errors of the restricted and unrestricted function; it presents an F distribution with one and (n - k) degrees of freedom (Kutsoyiannis, 1977).

$$F^* = \frac{SSE(r) - SSE(u)](n-k)}{SSE(u)}$$

where SSE(r) and SSE(u) are the sum of the squared residuals for the restricted and unrestricted function, respectively; n the number of observations, and k is the number of parameters in the unrestricted function.

The hypothesis to be tested are:

$$Ho: \sum_{i=1}^{p} B = 1$$

$$Ha: \sum_{i=1}^{p} B \neq 1$$

The procedure is (a) estimate the parameters for the unrestricted function and (b) estimate the parameter with the restriction on them.

Decision Rule:

If $F^* \leq F_{(\alpha;\ 1;\ n-k)}$ the test is insignificant and the null hypothesis, Ho, is accepted; the sum of the regression coefficients equal one. Reject Ho otherwise.

Test for a Set of Linear Restrictions

Considering a set of Q linear restrictions on the coefficients in different equations represented by the following matrix notation:

$$R\ \beta = r$$

where

R = Q x K matrix

β = K x 1 vector of coefficients

r = Q x 1 vector of restrictions,

The null hypothesis is that $R\beta = r$, is the true statistic, that is

Ho: $R\beta = r$

Ha: $R\beta \neq r$.

If the hypothesis is true, then the restricted generalized least squares estimator

$$\tilde{\beta} = \hat{\beta} + \delta R'[R\delta R']^{-1}(r - R\hat{\beta}),$$

with $\delta = (X'\ \Omega^{-1}\ X)^{-1}$, follows a $X^2_{(Q)}$ distribution with Q degrees of freedom.

The sample value of the test statistics is

$$X^2_{(Q)} = (r - R\beta)^1[R\delta R']^{-1}(r - r\beta),$$

Which is based on the estimators obtained from the ordinary least squares.

Decision Rule:

$$\text{If } X^2_{(Q)} \leq X^2_{(Q,\alpha)}$$

(the sample value is less or equal than the tabulated value at α level of significance), then the test is not significant and the null hypothesis, Ho, is accepted. $R\beta=r$ is the true statistic; reject Ho otherwise.